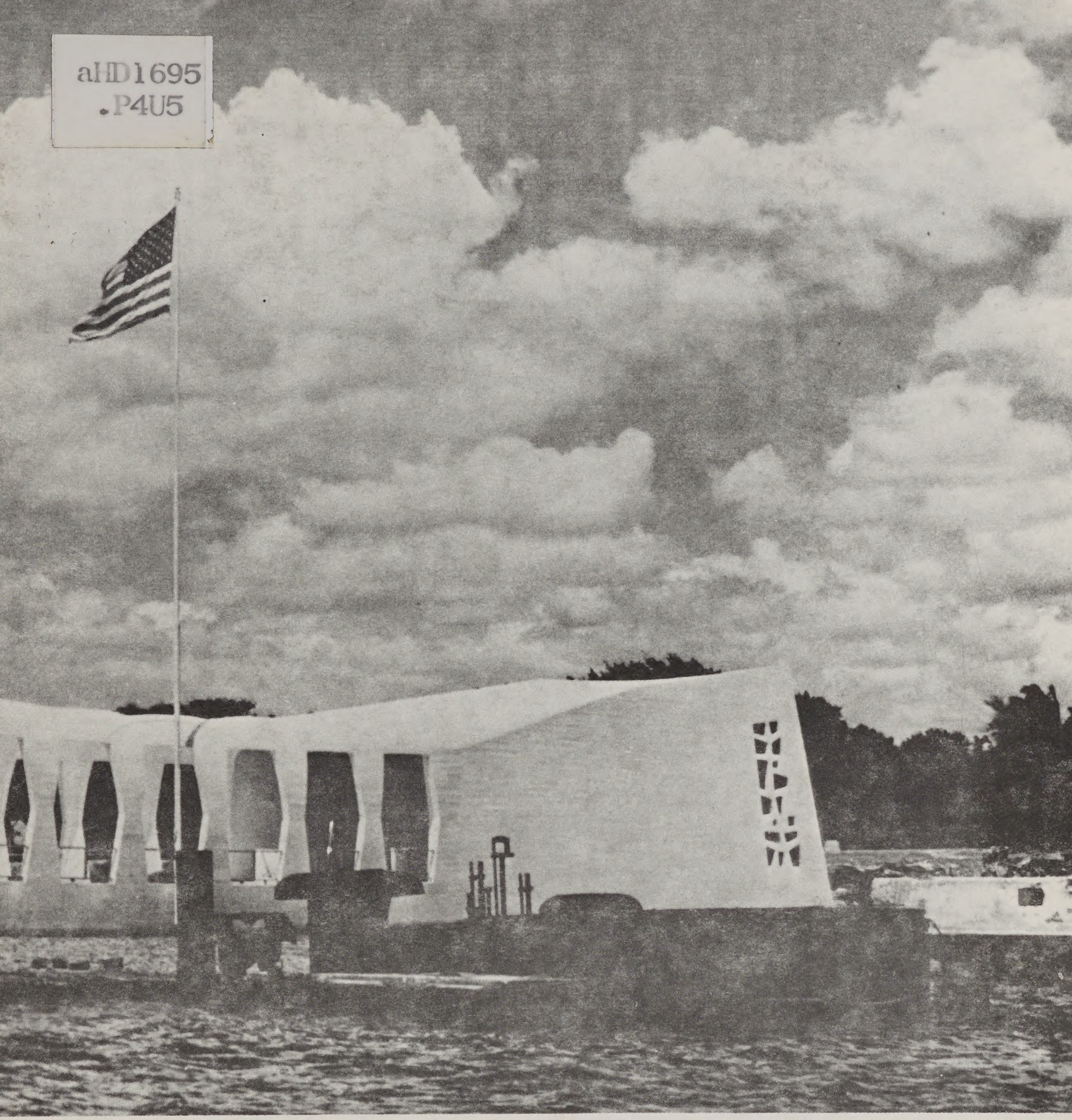

PEARL HARBOR BASIN
ISLAND of OAHU, HAWAII

Type IV River Basin Survey
June 1975

Appraisal of Alternative Means to Alleviate Erosion and Sedimentation Damages in the PEARL HARBOR BASIN

Island of Oahu, Hawaii

June 1975

A Report Based on a Cooperative Study by

HAWAII DEPARTMENT OF LAND AND NATURAL RESOURCES

and

U. S. DEPARTMENT OF AGRICULTURE

PREPARED BY:

Economic Research Service/Forest Service/Soil Conservation Service

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SUMMARY

This report by the USDA contains information on soil erosion, sedimentation, and other related problems in the Pearl Harbor Basin, Island of Oahu, Hawaii. It is a report of the cooperative Type IV River Basin survey of the Island of Oahu.

The State of Hawaii Department of Land and Natural Resources (DLNR) requested the Type IV survey and asked that the USDA give top priority to developing alternative plans for controlling soil erosion and sedimentation in the Pearl Harbor Basin. The study was made under the authority of Section 6 of the Watershed Protection and Flood Prevention Act (Public Law 83-566, as amended). DLNR's Division of Water and Land Development (DOWALD) participated in the study.

Objective and Scope of the Study

The major objective of the study is to develop and evaluate alternative plans that would reduce erosion and sediment damages in the Pearl Harbor Basin. Emphasis is placed on reducing sedimentation in Pearl Harbor because the harbor has been designated as the state's highest priority pollution problem by the Governor of Hawaii.

The study consists of: (1) a general appraisal of the soil erosion, sedimentation, and flooding problems in the Pearl Harbor Basin and potentials for solution; (2) an analysis of present and proposed programs for agricultural, urban, and forested lands; (3) development of alternative plans to reduce erosion and sediment damages through conservation practices, structural measures and land use changes; and (4) an evaluation of the environmental and economic effects of the alternative plans.

The Multiple Objective Planning and Evaluation procedure is used to evaluate the effects of the alternative plans. The beneficial and adverse effects of the alternatives on national economic development (NED), environmental quality (EQ), regional development (RD) and social well-being are displayed and provide a basis for comparing the alternatives.

Description of the Study Area

The Pearl Harbor Basin is located in the central part of the island of Oahu. Average annual rainfall ranges from 20 inches in the southern part of the basin to over 200 inches in the northeast.

Plantation agriculture (sugarcane, 20 percent; and pineapple, 9 percent), forest reserve (29 percent), and urban land[1/] (23 percent) uses predominate. Smaller areas are devoted to diversified agriculture, grazing and other uses.

The Pearl Harbor Basin had a population of 108,000 in 1970. Population has increased dramatically (over 60 percent increase) in the past decade and is projected to exceed 150,000 by 1980. Large amounts of nonurban land have been converted to residential subdivisions to accommodate the increased population.

Pearl Harbor is an estuary ideally suited as a harbor, a recreation area, and a habitat for fish and wildlife. Within the harbor, water quality has deteriorated over the years and present uses are restricted to defense activities, and limited commercial bait fishing and sightseeing.

Problems and Needs

Wide ranges of soil erosion occur in each land use category. Not all of any single category needs erosion control, but some land in each category requires treatment.

Urbanizing land requires the most protection from erosion. Removal of existing vegetation for residential and highway construction exposes the bare soil to rainfall and increases erosion hazard. Erosion continues after the houses are completed, since lawn establishment is left to the new owners. Erosion and sedimentation are greatly reduced in established urban areas.

Plantation agricultural lands are most vulnerable to extensive erosion damage during the period following harvest and before the new crop can protect the soil. The unpaved field roads often are water courses for sediment-laden runoff, and they also erode since their grades are excessive. Agricultural conservation and land management practices are widely used, but a need still exists for more grassed diversions, cover cropping, and other erosion control practices.

The forested lands are the steepest and generally receive the highest rainfall in the basin, but they contribute the least amount of sediment per acre because they are in good hydrologic condition and are distributed by few of man's activites. Periodic disturbances in forested lands include wildfires and landslides.

The most noticeable effect of soil erosion in the basin is the sedimentation in Pearl Harbor. After heavy rains, the near shore waters of the harbor turn red from the sediment-laden runoff. The problem is most prominent and persistent in West Loch, where there are potentially valuable oyster beds. The average sediment yield to Pearl Harbor from the watersheds in the basin is estimated at 96,230 tons/year.

1/ All land classified as "urban" under the State Land Use Law, include lands in urban use plus reserve areas (undeveloped land) for future urban growth.

Flooding is widespread and damaging throughout most of the basin. Agricultural lands, homes, businesses, and public improvements have been damaged by floodwater, sediment, and erosion. Construction of planned projects will alleviate flood damages in the Waimalu, Aiea, and Halawa watersheds. Average annual floodwater, sediment, and erosion damages in the other watersheds are estimated at $233,300.

Evaluation of Alternative Plans

Three alternative plans (A, B, and C) were evaluated and compared. Each plan consists of (1) recommended conservation practices, (2) structural measures, and (3) minor land use changes. The difference between Plans A, B, and C is the level of development of the structural measures. The conservation practices and minor land use changes are the same in all three plans. These plans provide significant sediment reduction without seriously disturbing agricultural production.

A linear programming (LP) model was used to estimate the losses in gross state output that would result from the land use change if required to meet certain levels of sediment reduction. The analysis is centered on the Honouliuli, Waikele, and Waiawa watersheds since they contain all the major agricultural lands that drain into Pearl Harbor.

Findings and Conclusions

1. Installation of currently planned conservation practices will reduce total sediment yield to Pearl Harbor from 96,230 to 84,600 tons/year, a 12 percent reduction. The individual watersheds would have the following sediment yield reductions after these conservation practices are installed:

    a. Honouliuli - 5 percent reduction--from 15,460 to 14,620 tons/year.

    b. Waikele - 10 percent reduction--from 55,750 to 49,980 tons/year.

    c. Waiawa - 6 percent reduction--from 12,710 to 11,980 tons/year.

    d. Waimalu - 37 percent reduction--from 11,670 to 7,380 tons/year.

    e. Aiea - no reduction from present sediment yield of 80 tons/year.

    f. Halawa - no reduction from present sediment yield of 50 tons/year.

2. Plan A, consisting of minor land use changes, recommended conservation practices and high priority structures, would reduce sediment yield by about 35,070 tons/year.

3. Plan B includes all of Plan A plus the low priority structures and would reduce sediment yield by about 41,950 tons/year.

4. Plan C is identical to Plan B except that the five structures in the Waikele watershed are replaced by a single larger structure. Plan C would reduce sediment yield by 60,190 tons/year.

5. Full development of all proposed (zoned) urban areas in the basin would reduce sediment yield by about 25,940 tons/year.

INTRODUCTION

Background

Pearl Harbor is a unique body of water ideally suited as a harbor, recreation area, and habitat for fish and wildlife. Located on Oahu's southern coast, this 9-square-mile area is protected from winds, severe wave action, and other natural forces. The state of Hawaii has established water quality standards to protect and enhance this valuable water resource.

Several uses of Pearl Harbor coexisted prior to World War II--naval activities, yachting, fishing, swimming, and collecting shellfish. Water quality has deteriorated over the years and present uses are restricted to defense activities, limited commercial bait fishing, and sightseeing. Population in the Pearl Harbor drainage area has increased dramatically since 1950 and the agricultural lands once surrounding the harbor have been converted to urban uses. This pattern is expected to continue. Federal, state, and local agencies are examining and evaluating the uses of Pearl Harbor. At present, pollution and unattractive esthetic conditions limit multiple use of harbor waters. The Governor of Hawaii designated Pearl Harbor as the highest priority pollution problem in the state after water quality standards were established in 1968.

The Administrator of the U. S. Environmental Protection Agency (EPA) called a conference concerning pollution of the navigable waters of Pearl Harbor and its tributaries in September 1971. The conference, involving the state water pollution control agency (Department of Health) and EPA, reviewed the situation to determine the program needed to correct the pollution problem. A remedial program to clean up the waters in Pearl Harbor was agreed to by the state and EPA. Conferees reached the following conclusions:

1. Pollution subject to abatement under the Federal Water Pollution Control Act exists in the interstate and navigable waters of Pearl Harbor. This pollution is caused by waste discharges from municipal, industrial, and federal facilities, agricultural activities, and urban development.

2. Measures taken thus far toward abatement of the pollution are inadequate to bring about its elimination within a reasonable period of time.

3. Delays being encountered in abating the pollution are caused principally by the complexity of the problem and the need for closely coordinated action by various levels of government and industrial establishments. However, formation of a Pearl Harbor Task Force by Governor Burns has assisted greatly in bringing about this needed coordination.2/

The conferees noted that, among the several pollutants, sediment has a major effect on water quality and the natural aquatic resources of Pearl Harbor:

> Sediment and debris are interfering with propagation of oysters and creating undesirable aesthetic conditions, reducing the water area and interfering with navigation. Where attributable to man's action, sediment discharges constitute a violation of State-Federal water quality standard.3/

Recommendations 12 through 15 of the conferees' report concerned the sediment pollution problem:

> 12. Erosion controls, as required by approved State-Federal water quality standards (Chapter 37A(6), State Public Health Regulations) shall be imposed on all State projects, and as a condition for issuance of all grading permits. It is also recommended that by July 1, 1972, the City and County of Honolulu amend their subdivision and grading ordinances to require that prior to issuance of permits, the permittee obtain a certification by the State Department of Health of the acceptability of the proposed erosion controls. It is further recommended that Federal loans and grants be withheld from housing, highway, and other construction projects which do not provide for erosion controls satisfactory to the State Department of Health.
>
> 13. The Oahu Sugar Company shall, by December 31, 1971, submit to EPA and the State Department of Health an acceptable program including a time schedule of actions leading toward (a) the elimination of mill waste and tailwater discharges to Pearl Harbor or its tributaries, and (b) control of soil erosion from its lands to the maximum feasible extent. This program shall be in full operation by December 31, 1974.

2/ U.S. Environmental Protection Agency, Proceedings - Conference in the Matter of Pollution of the Navigable Waters of Pearl Harbor and its Tributaries in the State of Hawaii, September 21-23, 1971, San Francisco, California.

3/ Op cit.

14. Major pineapple growers shall, by December 31, 1971, submit to EPA and the State Department of Health an acceptable program including a time schedule of actions leading toward the control of soil erosion from their Pearl Harbor watershed lands to the maximum feasible extent. This program shall be in full operation by December 31, 1974.

15. The State Department of Agriculture shall, in cooperation with the Oahu Soil (and Water) Conservation Districts, by July 1, 1972, develop a plan for a major study of soil erosion from undeveloped lands in the Pearl Harbor watershed. The study is to be completed not later than July 1974. The plan is to be acceptable to the State Department of Health and the Environmental Protection Agency.4/

The City and County of Honolulu enacted a new grading ordinance in response to the requirements of paragraph 12 of the Pearl Harbor Enforcement Conference. Erosion controls are required in all grading operations and proposed control measures must be certified acceptable by the State Department of Health prior to issuance of grading permits.

The new grading ordinance requires erosion controls in all grading operations. Major features of the grading ordinance include:

1. Provisions that noncontiguous areas can be graded if soils, climate and adequate erosion control measures allow it and no single parcel exceeds 15 acres.

2. Natural vegetation should be retained whenever feasible.

3. Requirement that temporary structural measures be provided to control erosion during grading until protective vegetation provides adequate cover.

4. Dust control and conformance to state water quality standards requirements.

Erosion control measures are also imposed on all projects sponsored by the state of Hawaii. Conservation measures being applied on the urbanizing lands include:

1. Sediment basins, diversion channels, and ditches with adequate outlets.

2. Revegetating exposed areas, especially cut-and-fill slopes.

4/ Op cit.

3. Incremental site clearing.

4. Stream channel and bank stabilization.

5. Grassed waterways.

6. Site watering to suppress dust.

The major agricultural interests in the Pearl Harbor Basin, responding to paragraphs 12 and 14 of conferees' report, updated their conservation programs and are implementing measures to control soil erosion from their lands. All of these programs were developed with the aid of the SWCDs and SCS. The programs for the agricultural lands also call for continuing assistance from SCS in the design and application of specific conservation practices.

The State Department of Agriculture asked DLNR to respond to paragraph 14 since DLNR provides administrative support to the soil and water conservation districts (SWCD) and works closely with them. DLNR then requested that the U.S. Department of Agriculture (USDA) undertake a cooperative Type IV River Basin Study for the island of Oahu and give top priority to preparing a report on controlling soil erosion and sedimentation in the Pearl Harbor Basin. The USDA agreed to participate in the Type IV study under the authority of Section 6 of Public Law 83-566, as amended. The USDA agencies participating in this study are the Economic Research Service (ERS), the Forest Service (FS), and the Soil Conservation Service (SCS).

While Paragraph 15 deals specifically with soil erosion on undeveloped lands, an effective program to control sedimentation in Pearl Harbor depends upon consideration of all lands in the drainage area--agricultural, urban, and forested lands. Measures to provide additional benefits to flood prevention, water supply, recreation, and wildlife should be considered in the development of sediment reduction plans.

Objectives

This study of soil erosion and sedimentation in the Pearl Harbor Basin has three major objectives:

1. To determine the nature and extent of soil erosion from various land uses in the basin and estimate the amount of sediment entering Pearl Harbor.

2. To develop and evaluate alternative plans that would reduce erosion and sediment damages through conservation practices, land use changes, and structural measures and estimate the costs of such plans. Multiple benefits will be considered in the development of these alternatives.

3. To recommend priorities for project installation, and to evaluate the physical and economic effects of project measures.

Scope of the Study

The lands draining into Pearl Harbor comprised the study area for this report.

Reconnaissance level investigations were made in the Pearl Harbor Basin to develop a general appraisal of the flooding, erosion, and sediment problems, and potentials for solution. Problem solutions included different levels of development, timing and priority of action, and land use regulation or change. The intensity of the studies was sufficient to provide guidance for detailed planning of specific projects.

Present practices, problems, and programs were analyzed, along with the proposed programs for agricultural, urban, and undeveloped lands. This analysis provided a base for developing a coordinated program to reduce sedimentation in Pearl Harbor. Watersheds were studied to determine the approximate project benefits and costs and the impacts of the project on the environment.

Reduction of sediment yield from landslides, streambank erosion, and other forms of erosion occurring in the undeveloped lands was a major concern of this study. The program for these lands was formulated in coordination with the conservation plans for the various agricultural and urban lands. DOWALD, two Oahu SWCDs, and SCS coordinated the activities of the many agencies and organizations to arrive at a workable program and eliminate duplication of efforts. Maximum use was made of existing studies and reports.

DESCRIPTION OF THE STUDY AREA

Physical Data

The study area encompasses 92,630 acres, nearly 145 square miles, in the central part of the island of Oahu (Figure 1). The area constitutes about 30 percent of the island and includes eight streams that discharge into Pearl Harbor. Two of these streams are intermittent: Honouliulu Stream which discharges into West Loch, and Aiea Stream which discharges into East Loch. The perennial streams (Waikele, Waiawa, Waiau (Waimano), Waimalu, Kalauao, and Halawa) have their headwaters in the high rainfall area of the Koolau Range. All streams drain forested and agricultural lands, then pass through urban areas before entering Pearl Harbor.

Predominant land uses in the study area are plantation agriculture, forest reserve, and urban. Smaller amounts of land are devoted to diversified agriculture, grazing, and other uses. Land use in the Pearl Harbor Basin is shown on Figure 2 and discussed in the following section.

Soils and topography are influential factors in determining erosion and sediment yield. Soils on Oahu were identified and mapped in the soil survey of Oahu.5/ The General Soil Map (Figure 3) identifies the broad patterns of soils found in the Pearl Harbor Basin.

The Erosion Hazard Map (Figure 4) shows relative susceptibility of soils to erosion when vegetative cover is removed. The soils are rated as having slight, moderate, or severe erosion hazard, based on soil properties including slope and aggregate stability. Most of the Koolau and Waianae ranges and the deep gulches that dissect the central plateau are classified as having severe erosion hazard primarily because of their steep slopes and high rainfall. The lower slopes of the Koolau and Waianae ranges and parts of the central plateau have moderate erosion hazard. The coastal plains and most of the central plateau have slight erosion hazard. The erosion hazards provide the basis for developing erosion control programs.

The basin's geology influences the types and amounts of erosion occurring and is shown on Figure 5.

The vegetation types which evolved from their adaptability to particular soils, topography, and climate also affect soil losses. The major categories of vegetative cover are shown on Figure 6.

5/ U.S. Department of Agriculture, Soil Survey of the Islands of Kauai Oahu, Maui, Molokai, and Lanai, State of Hawaii, Soil Conservation Service, in cooperation with the University of Hawaii Agricultural Experiment Station, August 1972.

Rainfall is the dominant climatic factor affecting the environment and erosion. Average annual rainfall varies from 20 inches in the southern part of the study area to over 200 inches in the northeastern mountainous area. Ranges of average annual rainfall are shown on Figure 7.

The Pearl Harbor Basin's fish and wildlife resource is a significant source for recreation and scientific interest, and could become more important economically. One parcel of land in the brush covered area between Waimano and Waiawa streams, about 500 acres in size, is a heavily used public hunting area. It is the only publicly hunted area in the basin. Of more importance in wildlife management are the areas identified as important to endangered species of native birds. Six areas are already set aside, on the shores of the harbor, as refuges for the protection of native shorebirds, with another area being studied for their protection (see Figure 9). These refuges total 390 acres, and are located on all lochs in the harbor. In the higher elevations in the Koolaus, another 1,500 acres has been identified as primary range for native forest birds. None of these areas will be directly affected by the stream projects, except that reduced sedimentation will reduce the impacts on the shorebird refuges further downstream.

The fisheries resource will be directly affected by the projects. Although there is no freshwater fishery in the study area, the brackish waters of Pearl Harbor are already productive as a source of sports fishing and are the most important source of nehu, the most important baitfish in the state. With reduced pollution, the fishery will become an important source of shellfish such as clams, crabs, oysters, and prawns. There are also two commercial fishponds near the shores of the harbor. What is already said to be a several million dollar industry could grow severalfold with improved water quality and management.

Economic Data

The upper mountainous areas along both sides of the basin consist of forested lands. On the Waianae mountain side of the basin, the lower slopes are interspersed with brush, pasture, and sugarcane. Pineapple and sugarcane are grown in the central plateau with some vegetable production in the flood plain areas of the gulches. The lower Koolau mountain side is primarily developed into urban area. The distribution of land uses in the Pearl Harbor Basin is shown in Table 1.

Table 1. Land Use Distribution - Pearl Harbor Basin, 1970

Land Use	Acres	Percent
Plantation Agriculture:		
Sugarcane	18,260	20
Pineapple	8,600	9
Pasture	2,950	3
Diversified Agriculture	540	1
Forest: Forest Reserve	27,300	29
Outside Reserve	5,860	6
Other	8,270	9
Urban District*	20,850	23
TOTAL	92,630	100

*All land classified as Urban under the State Land Use Law, includes lands in urban use plus reserve areas (undeveloped land) for future urban growth.

Landownership in the study area is highly concentrated and several large owners control most of the land. Major federal holdings surround Pearl Harbor and the Wahiawa-Schofield Barracks area. The state holds two large parcels of land--agricultural land near Wahiawa and forest reserve land near Pearl City. Between Pearl City and Wahiawa, four large estates or corporations (Bishop, Castle and Cooke, Robinson, and Campbell) each hold large wedges of land radiating inland from Pearl Harbor. Many small fee simple parcels exist in the basin and are mostly in urban use. The pattern of landownership is shown on Figure 8.

Most of the crop and pastureland is owned by large estates and leased to Oahu Sugar Company, although there is significant pineapple production in the area. Approximately 52 percent of the county's and 16 percent of the state's raw sugar production is located in the basin. Pineapple production accounts for about 57 percent of the county and 15 percent of the state total. Most of the forest areas, though privately owned, are managed under surrender agreement by the DLNR as forest reserves.

Population in the basin has increased from 66,600 to 108,000 in the 1960-70 period and is expected to expand to over 150,000 by 1980. This increase in population will be accompanied by new transportation, school, recreational, shopping, and housing developments. The basin also contains much of the state's industry, including Hawaii's only sugar refinery, and one of the island's two sugar mills.

PROBLEMS AND WATERSHED CONDITIONS

This section describes the general nature of soil erosion and sedimentation problems in the Pearl Harbor Basin, the effects of sedimentation in Pearl Harbor, the general watershed conditions, and the specific problem areas in each watershed. The problems identified in this section guided the development of project measures to control soil erosion and reduce sedimentation in the basin.

Soil Erosion

The amount of soil erosion from any given part of the basin is governed by the slope, soil, vegetative cover, rainfall, and land use. Land use and slope are the most important factors and vary from the relatively untouched steep forest reserves to the completely denuded, developing urban lands. Althouth denudation is a one-time occurrence for urban development, the erosion rate is higher per acre than that for any other land use.

The plantation agricultural lands are most vulnerable to extensive erosion damage during the period after harvest and before a protective canopy can develop. Permanent erosion scars are not evident because harvesting and planting operations obliterate rills, headcuts, and other erosion signs.

Sugarcane and pineapple lands are most vulnerable to erosion damage during the period after harvest and before a protective canopy can develop.

Sugarcane in the basin is harvested on a 24-month cycle. The sugar industry is highly mechanized in their methods of harvesting, which consist of burning to remove most leaves and using large machinery to harvest the cane. These methods add to the erosion potential problems. Cultivation of steep slopes and the many field roads have also added to the erosion problem in the cane fields.

The pineapple harvesting methods are not as highly mechanized as sugarcane, but pineapple has the same kinds of erosion problems as sugar--cultivating steep areas, many field roads, and no protective cover after planting.

About 1,550 acres of grazing land in the interior region is in poor condition with sparse grass cover. Poor land management in the past, as well as low rainfall and extremely acid soils, have tended to retard grass recovery.

Diversified agricultural land has the same kinds of erosion problems as the plantation agriculture, only on a smaller scale.

The gulches in the basin generally have good cover in their middle and lower reaches. The steepest portions of these gulches contain large areas of bare, sparsely vegetated, eroding ground. Most of the critical eroding areas (1,630 acres) are along the gulches.

The forested lands, although the steepest and having the heaviest rainfall, contribute the least sediment per acre because they are in good hydrologic condition and are disturbed by few roads, trails, or industrial activities. The only significant disturbances are wildfire and landslides which contribute most of the sediment from forest lands. Over 2,000 acres of brushland were converted to commercial forest types prior to 1955. Additional plantings may be established, but harvesting is not anticipated in the near future.

Sedimentation in Pearl Harbor

The amount of soil transported to Pearl Harbor by the streams is estimated at 96,230 tons per year (64 acre feet). Table 2 contains the estimated annual sediment yield to Pearl Harbor from the watersheds in the basin. The yields vary with the watershed size, land uses, rainfall, vegetation, and soils.

Table 2. Estimated Sediment Yield to Pearl Harbor by Watersheds - Pearl Harbor Basin

Watershed		Estimated Sediment Yield tons/year
West Loch -	Honouliuli	15,460
	Waikele	55,750
Middle Loch -	Waiawa	12,710
East Loch -	Waimalu	11,670
	Aiea	80
	Halawa	560
	TOTAL	96,230

After any heavy rain, the near-shore waters of Pearl Harbor turn red from the sediment-laden runoff. The distinct reddish color is most prominent and persistent in the waters of West Loch.

Sediment fans have accumulated in most streams at their entrance to Pearl Harbor. Sediment deposits are filling in the upper end of West Loch where depth of silting exceeds 8 feet in some areas. Portions of East Loch are too shallow for even a medium-sized skiff.6/ The U. S. Navy spent over $1.9 million in the 8-year period ending in 1969 to dredge the harbor and maintain navigable channels. Dredging operations have increased significantly during the past 5 years.

6/ U.S. Department of the Interior, Report on Pollution of the Navigable Waters of Pearl Harbor, Federal Water Pollution Control Administration, Pacific Southwest Region (now Environmental Protection Agency), San Francisco, California, October 1969; with Addendum, August 1971.

Probably the most severe water quality problem occurs in West Loch where oyster beds are located. The upper end of West Loch, which contains these beds, is designated as Class AA waters by the State of Hawaii Water Quality Standards. The Class AA is designed to protect the following uses:

> ...oceanographic research, propagation of shellfish and marine life, conservation of coral reefs and wilderness areas, and aesthetic enjoyment. It is the objective of this class of waters that they remain in as nearly their natural, pristine state as possible with an absolute minimum of pollution from any source.7/

Sediment deposits from Honouliuli Stream (lower half) and Waikele Stream (upper right) create severe water quality problems in West Loch, Pearl Harbor. Note deltas being formed at stream mouths.

7/ Department of Health, State of Hawaii, Public Health Regulations Water Quality Standards, Chapter 37-A, Sec. 3 & 5.

Presently, the area designated as Class AA has the poorest quality water of any area in the harbor. The heavy sediment loads have reduced the number of oysters in some of the beds by more than 90 percent during the 9-year period ending in 1971. While other beds experienced increases of 60 percent, total overall losses have exceeded gains by about 3 percent.8/

The State Division of Fish and Game is currently trying to develop the oyster beds. Conservative estimates by EPA indicate that the oyster resource in West Loch has a minimum potential value to the grower (state of Hawaii) of approximately $480,000 per year.9/

Watershed Conditions

Three major land uses occupy 91 percent of the land in the Pearl Harbor Basin. These are: forest (35 percent), agricultural (33 percent), and urban, which includes military uses (23 percent). Current land treatment and management practices on these lands are discussed in this section.

Forest Lands--Ownership of forest lands consists of private, state, and federal holdings. The federal lands administered by the Department of Defense make up 13 percent of the forested lands. The management objective has been, with the exception of some tree plantation establishments, to protect the land from fire and natural disasters.

Private land, by far the largest ownership class (69 percent), varies in management programs. However, considerable private acreage is being administered as forest reserves by the State Division of Forestry through an arrangement known as a surrender agreement. This process allows the landowner to retain ownership in the land, while turning over the management and protection of the land to the Division for specified periods of time.

The Division also administers the state-owned forest lands. Their activities on lands they administer stress watershed protection. Present activities are aimed at the recreational and esthetic potentials of these lands, as well as the long standing objectives of erosion control and water quality improvement. Timber growing or harvesting has not been a major goal.

8/ State of Hawaii Department of Land and Natural Resources, A Resurvey of the Oyster Resources in West Loch, Pearl Harbor, September 1971.

9/ Op cit.

Disturbances such as fire and natural landslides occur periodically on forested land. Efforts by the Division of Forestry at revegetation by either seeding, planting, or structurally holding the soil in place have minimized erosion damages.

Future management activities on forested lands will include improving wildlife habitat and maintaining the quality of water flowing from these lands.

Agricultural Lands--Practically all of the agricultural lands are in large plantation-type operations controlled by the Oahu Sugar Company (sugarcane), Del Monte Corporation (pineapple), and the Dole Company (pineapple). These companies have developed and are implementing soil and water conservation programs.

Oahu Sugar Company controls all of the sugarcane land (18,260 acres) and about 1,700 acres of pasture and other land. On the sugarcane lands, the following conservation practices are being applied or planned:

1. Protective cover, including crop residue use to reduce soil losses. Other practices to maintain good cover include reduced raking on steep, hilly areas and weed control on drainage ditches and streambanks.

2. Contour farming where sugarcane is planted in furrows on a graded contour with grades of 1.5 percent or less to reduce surface water movement and soil loss.

3. Grassed waterways to reduce runoff velocities and minimize bank erosion.

4. Irrigation water management to use water efficiently and eliminate tailwater discharges. About 60 irrigation tailwater sediment ponds have been constructed resulting in no tailwater discharge into Pearl Harbor.

5. Diversion to slow overland runoff and soil movement.

6. Cropland conversion to permanent vegetation - To retire from cultivation of steep areas on which erosion control measures are impractical.

Oahu Sugar Company has installed about 60 percent of its total planned conservation practices. The company plans a systematic conversion to drip irrigation. There is a concern that conversion to drip irrigation will increase erosion problems. Therefore, other needed control measures will be installed as fields are converted to the new system.

The pastureland owned by Oahu Sugar Company is leased to private livestock operators. These leases require that a good grass cover be kept on the land and that noxious weeds be controlled.

On the pineapple lands, the following practices and measures are being applied:

1. Diversions.

2. Contour farming.

3. Quick cycling or replanting as soon as possible to reduce time that fields are left without protective cover.

4. Crop residue used to reduce impact of raindrops, reduce erosion, and increase water intake.

5. Deep plowing to improve water intake rates and reduce runoff.

6. Debris basins and sediment ponds to trap runoff, debris, and sediment before it leaves the fields.

On noncropland, the pineapple companies have installed the following measures and practices:

1. Tree planting to reduce erosion and increase infiltration and improve aesthetics.

2. Debris basins.

3. Grassed waterways.

Del Monte Corporation, which controls about 4,500 acres, or 52 percent of the pineapple land in the basin, has installed about 85 percent of its planned conservation practices. All planned measures will be installed in 1978. The remaining 4,100 acres of pineapple land is controlled by the Dole Company, which has installed all of the conservation practices described in its conservation plan. All conservation systems are checked periodically and maintained to insure the effectiveness of the installed measures.

Urban Lands--The Pearl Harbor Basin has the highest population growth rate (over 60 percent increase from 1960-1970) and the lowest residential densities (2.1 housing units per urban acre)

of any area on Oahu.10/ The low residential density is due to urban zoned acreages with, as yet, no residential developments. Large amounts of non-urban land have been converted to suburban subdivisions to accommodate the increased population. Since 1964, nearly 6,000 acres of agricultural land have been rezoned for urban use. Most of the rezoning has taken place in the Waikele and Waimalu watersheds. Present plans by the City and County of Honolulu11/ and the State of Hawaii12/ call for residential development in urban areas where open space and other amenities can be provided. Continuation of present trends will result in further loss of prime agricultural land and open space.

Agricultural lands are constantly under pressure for conversion to urban use.

10/ Department of Planning and Economic Development, Central Oahu Planning Study - Environment and Urbanization in Central Oahu--A Resource Base Analysis, Tech, Supp. 1, January 1973.

11/ Department of General Planning, City & County of Honolulu, Alternatives for Residential Development.

12/ State of Hawaii Department of Planning & Economic Development, Selected Growth Policies Plan, March 1975.

Urban development is a major cause of erosion in the basin. Clearing the land for residentail and highway construction exposes the soil to rainfall and increases erosion hazard. The heavy equipment used in land clearing and construction also compacts the soil, thereby reducing infiltration and increasing runoff and erosion.

While the urbanizing lands contribute the largest amount of sediment on a per-acre basis, erosion and sedimentation are greatly reduced once these areas become established. However, increased runoff usually results since vegetative cover is often replaced by impervious surfaces, such as asphalt, concrete, and building roofs.

Watersheds

Ewa Beach Watershed--Only 20 percent (2,700 acres) of this watershed drains into Pearl Harbor. Kaloi Gulch drains most of the watershed and discharges directly into the Pacific Ocean along the coast west of Ewa Beach. Sediment discharges into Pearl Harbor from the flat, lowland area adjacent to West Loch are negligible.

The Tenney and Varona villages, part of Ewa town, contain about 80 homes that are subject to flood damage. The existing Kaloi Gulch channel is adequate to carry runoff from a 5-year storm. Storms of greater magnitude would cause severe damage to sugarcane lands, residences, and public improvements. Average annual flood damages in the watershed are estimated at $25,000. Flood-prone areas in the watershed are shown in Figure 11A.

Honouliuli Watershed--Honouliuli Stream discharges intermittently into West Loch and drains an area of 12 square miles of primarily agricultural and forested land. The upper watershed, consisting of steep forest, pastures, and sugarcane fields, is subject to intense rainfall and erosion damages of varying degrees. The eroded soils carried downstream by floodwaters cause damages in the flood plain and contribute to the sediment pollution of Pearl Harbor. Six hundred thirty-five acres in scattered parcels of the upper watershed are eroded enough to warrant stabilization. These parcels, which are poorly managed pastures, can be replanted to trees and shrubs to arrest their erosion. Such programs as the Cooperative Forest Management program could aid these upper watersheds, not only by planting trees in the critical areas but working towards improving the forested areas as a whole.

The flood plain downstream of Fort Weaver Road is subject to flooding due to the inadequate capacity of the stream channel. In addition to the nearly flat gradient and sharp bends of the stream, channel capacity is reduced by debris, dense vegetation, and man-made constructions. Floodprone areas on Honouliuli Stream are shown on Figure 11A.

Most of the watershed's population is located in Honouliuli village, where the principal damages occur. Floodwater and sediment has damaged agricultural land, residences, businesses, and public improvements. Some degree of property damage has occurred along the stream almost every year and, occasionally, lives have been lost.

The storm of January 23, 1972, estimated to have an average recurrence interval of 3 years, damaged approximately 185 acres and several residences. Runoff from the 100-year storm would inundate about 250 acres. Average annual floodwater, sediment, and erosion damages in the watershed are estimated at $84,400.

Floodwaters overflow Honouliuli Stream and damage pasture, sugarcane and homes.

Waikele Watershed--Waikele Stream and its tributaries drain most of this 54-square-mile watershed, which constitutes nearly 40 percent of the Pearl Harbor Basin. The stream receives significant runoff from the high mountain areas. About 10 miles of Waikele and Kipapa Streams are controlled by the military and used primarily for munition storage. Waikele Stream discharges the heaviest sediment load of any of the Pearl Harbor Basin streams.

The watershed has serious erosion problems on the sides of the gulches. The bare areas, caused mostly by vehicular traffic, construction, and agricultural activities are located throughout the drainage system to the forest reserve boundary. Several large forest fires have also occurred here.

There are several flood-prone residential areas in the watershed. About 15 homes are presently subject to damage on Waikakalaua Stream tributary above Kam Highway. More units are being planned and built in the damage area (Figure 11B). Along Waikele Stream about 12 homes and a water pumping station are subject to damage in the area between the Naval Reservation and Farrington Highway (Figure 11C). Flood channel improvements along the lower reaches of Waikele Stream have effectively reduced flooding between Farrington Highway and Pearl Harbor. The residential area near Waipahu Field and part of the field itself are also subject to damage (Figure 11C). The small, flat stream through the area overflows during large storms. Average annual flood damages for the watershed are estimated at $49,400.

Waiawa Watershed--Waiawa Stream and its tributaries discharge into Middle Loch and drain an area of 24.6 square miles of forest, agricultural, and urban land. Erosion damage in the sugarcane, pineapple, and forested areas occurs during all major storms. The effects of these soil losses are reduced stream capacity and increased sediment pollution of Pearl Harbor. Most of the pineapple lands lie fallow and have been proposed for urban development.

The lower part of Waiawa Stream meanders from Farrington Highway to Middle Loch, carrying perennial flow into Pearl Harbor. The stream capacity has been reduced in this area by deposition and the stream overflows as often as six times a year. Flooding damages crops, residences, and public property.

Damage in the agricultural area of the flood plain occurs primarily to small farms raising livestock, fruits, watercress, taro, and other vegetables. The University of Hawaii agricultural facility is also located in this area and suffers damage.

Watercress and banana farms along Waiawa Stream are damaged by floodwaters.

About 46 homes--mostly low income family dwellings--would be damaged by the 100-year flood. Average annual flood damages for the watershed are estimated at $74,500. Flood-prone areas in the watershed are shown on Figure 11C.

Waimalu Watershed--The Waimano, Waimalu, and Kalauao Streams drain this 17.7-square-mile watershed and discharge into the East Loch of Pearl Harbor. The watershed is primarily undeveloped forest land with established urban areas on the coastal plain and lower slopes. Urbanization is increasing on the mid-slopes. Flood-prone areas in the watershed are shown on Figure 11C.

Sediment deposition reduces the capacity of the lower part of Waimalu Stream, which meanders to Pearl Harbor. Constant maintenance is needed to assure adequate channel capacity and prevent flood damages to adjacent residential areas and public improvements.

The Waimano Stream, which drains the Pearl City area, has been subjected to urban encroachment and does not have the capacity for the increased runoff from the new residential subdivisions. Portions of the present channel are unstable under high velocity flows. The storm of March 1968 demonstrated these inadequacies when stream overflow damaged homes and a shopping center and long reaches of the streambed lining were torn out.

Floodwaters overflowed the Waimano Stream and damaged the Pearl City Shopping Center complex during a storm in 1968.

The U.S. Army Corps of Engineers has proposed a flood control project for Waimano Stream, consisting of a new concrete channel above the shopping center.13/ This channel, in conjunction with a relief drain proposed by the City and County of Honolulu, would greatly increase the capacity of Waimano Stream and enable it to carry runoff from a 100-year storm without flooding.

13/ U.S. Army Corps of Engineers, Pacific Ocean Division, Hawaii - Water Resources Development, Fort Armstrong, Hawaii, January 1972.

PHYSICAL POTENTIAL FOR REMEDIAL MEASURES

Erosion and sedimentation control measures can be either vegetative or structural, or a combination of both. The programs for the agricultural and urban lands in the basin consist of measures that control erosion and sedimentation by application of practical combinations of the following principles:

1. Fit development plans to the topography, soils and vegetative cover to reduce erosion.

2. Retain and protect suitable existing vegetation wherever possible to retard runoff and erosion.

3. Provide structural measures to accommodate increased runoff resulting from changed soil and surface conditions.

4. Install permanent vegetative and structural erosion control and drainage measures to stabilize disturbed areas.

5. Maintain vegetative and structural improvements to insure their effectiveness.

6. Adjust land use to assure that flatter lands are used for cultivated crops and steeper lands to permanent pasture or forest.

No distinction is made between agricultural and urban erosion control and sediment reduction practices because the design criteria, and not the definition of practices, change for different land uses.

Climatic and soil conditions in the basin are favorable for establishing adapted plants to control runoff and erosion. Where erosion is unavoidable, sediment basins are required to help keep the soil from eventually reaching Pearl Harbor.

Several favorable sites for large sediment basins are found on the major streams or their tributaries in the study area (see Formulation of Alternative Plans). These sites also provide opportunities for recharge of the ground water resources. Sites of the Honouliuli and Waiawa Streams also offer opportunities for significant flood damage reduction. Although surface water in the forest reserve areas is of good quality, base flows are insufficient to justify development as water supply sources. The permeability of the basin's soils and rocks also render these sites impractical for storage reservoirs.

Sediment yield can be reduced by changing the pattern of land use in the Pearl Harbor Basin. Various levels of sediment reduction can be achieved through land use changes. However, substantial reduction in sediment yield based on land use change would have damaging effects on the agricultural economy of Oahu.

Existing studies14/ indicate that about 50 percent of the suspended sediment carried by streams in the Pearl Harbor Basin consists of very fine particles (less than 0.004 millimeter). These very fine particles, which are responsible for the turbidity in Pearl Harbor after heavy rains, constitute about 30 percent of the total sediment load.

It is primarily the coarse sediment that is more readily controlled with available technology. Erosion control systems will reduce the amount of fine material reaching the streams. However, complete elimination of the very fine particles requires complex, costly processes, such as flocculation, coagulation, precipitation, and filtration. Turbidity in Pearl Harbor may continue to be a problem as no acceptable minimum turbidity levels and standards are available at present. Complete elimination of erosion is virtually impossible, and guidelines are needed to define acceptable levels of erosion and sedimentation in the Pearl Harbor Basin, especially as they pertain to water quality and multiple use of harbor waters.

14/ Jones, B. L., R. H. Nakahara, and S. S. W. Chinn, Reconnaissance Study of Sediment Transported by Streams on the Island of Oahu, Hawaii, U.S. Geological Survey, Honolulu, Hawaii, 1971; and other unpublished USGS data.

FORMULATION OF ALTERNATIVE PLANS

The objective of reducing erosion and sediment damages guided the formulation of project measures. A coordinated system of conservation practices, land use adjustments, and structural measures would provide the greatest reduction in sediment yields. Flood prevention was also included as a project purpose in the Honouliuli and Waiawa Watersheds where significant flood damages have occurred.

Various types and sizes of sediment reduction and flood prevention measures were compared and evaluated. Alternate locations and construction types were also compared. A linear programming model (LP) was used to estimate the effects of changes in land use and land management practices on agricultural production and the agricultural sector of the island economy.

This section discusses the conservation practices, structural measures, and land use change alternatives to reduce sediment yields to Pearl Harbor. The costs, benefits, and impacts of the various measures are described and priorities for installation are identified.

Conservation Practices

The major agricultural interests in the basin are implementing their conservation programs. These programs which are at various stages of completion were examined and their effects on sediment yields estimated. Installation of their planned conservation practices would reduce annual sediment yields by an estimated additional 5 percent on the Honouliuli Watershed, 10 percent in Waikele, and 6 percent in Waiawa. Annual sediment yield to Pearl Harbor from these three watersheds would be reduced by about 9 percent, or 7,340 tons, after these planned measures are installed.

Implementation of the erosion and sediment control practices required by the City and County grading ordinance would reduce sediment yield from the urbanizing Waimalu Watershed by 37 percent, or an estimated 4,290 tons per year.

Further reductions in sediment yield will require additional conservation practices beyond those presently planned. The recommended program consists of additional measures on agricultural land and on severely eroding areas outside the croplands.

The additional conservation practices for the various watersheds are listed in Table 3. Installation of these measures will reduce total annual sediment production by about 13,570 tons (16 percent reduction), at a cost of $528,500. This amounts to a cost of $160 per acre or $.26 per ton of sediment reduction for the life of the conservation measures.

Structural Measures

Structural measures are needed to supplement the conservation practices to further reduce sedimentation in Pearl Harbor. Since sediment basins are one of the most effective ways of curtailing off-site sediment damages, investigations proceeded toward locating and evaluating potential sediment basin sites.

Only structures in the agricultural areas were evaluated. The City and County of Honolulu grading ordinance provides for erosion and sediment control measures in other areas. Erosion and sedimentation in developing areas would be adequately controlled by strict adherence to the grading ordinance. In established urban areas, erosion is drastically reduced, although runoff increases, and large sediment basins would not be needed.

Over 20 potential sites in the Honouliuli, Waikele, and Waiawa Watersheds were identified and evaluated. Site selection was based on (1) topographic, soils, and geologic conditions; (2) present land use; and (3) size of the drainage area controlled. Most of the sites are located in small- or medium-sized gulches in brush covered lands where koa haole (Leucaena leucocephala), guava (Psidium guajava), and lantana (Lantana camara) are the most common vegetation. Several favorable sites were found in the large gulches of the Waikele Watershed but are located within the military reservations. One large site on Waikele Stream was evaluated since it could provide substantial sediment reduction benefits.

Analysis of the potential sites resulted in the selection of 13 where structures would provide maximum benefits at the least cost (Figure 10). All structures have capacity for sediment retention. In addition, the two structures on Honouliuli Stream (HOL-1 and HOR-1) and one on Waiawa Stream (WAI-1) have capacity for controlling floodwater. The structure of Waiawa Stream (WAI-1) would also have capacity and potential for recreational use, in accordance with the desires of the local people who have submitted an application for assistance under PL-566. The structures would be earthfill dams with concrete spillways and drain facilities. Pertinent structural data is in Table 4.

Honouliuli Watershed--The two dams would be flood prevention/sediment retention structures that would reduce sediment yield by about 9,200 tons/year. The structures would also protect 250 acres of cropland, pastureland, and residential areas from severe flood damages.

Average annual flood damage reduction benefits are estimated at $61,200. Sediment reduction benefits in Pearl Harbor consisting of decreased dredging costs, potential oyster sales, and recreational use by the public are estimated at $48,400 per year. Other benefits would include aesthetic and environmental improvement and land enhancement.

Table 4. Structural Data - Pearl Harbor Basin

Location		Site I.D. No.	Drainage Area (Acres)	Storage Capacity (Ac-Ft)			Surface Area (Acres)		Embankment Data		Total Installation Cost[1/] ($1,000)	Annual Cost[2/] (Dollars)
Watershed	Stream			Sediment	Floodwater	Total	Sed. Pool	Flood Pool	Max. Hgt. (Ft)	Fill Volume (CY)		
HONOULIULI												
	Left Branch	HOL-1	3,390	71	1,444	1,515	8	48	85	455,000	1,677	105,620
	Right Branch	HOR-1	2,675	56	1,006	1,062	5	41	90	334,000	1,267	79,780
WAIKELE												
	Poliwai	POL-1	6,598	231	-	231	8	-	79	146,000	695	44,010
	Waikele	WKL-2	3,563	143	-	143	12.5	-	35	45,000	434	27,440
	"	WKL-3	262	11	-	11	3	-	17	8,000	104	6,580
	"	WKL-4	474	20	-	20	7	-	17	29,000	297	18,770
	Kipapa	KIP-2	460	19	-	19	2	-	26	10,000	117	7,410
	Waikele	WKL-1[3/]	29,760	2,896	-	2,896	88	-	89	340,000	2,097	132,080
WAIAWA												
	Panakauahi	PAN-1	1,972	69	-	69	3.5	-	44	47,000	305	19,340
		PAN-2	1,655	67	-	67	6	-	35	27,000	247	15,650
		PAN-3	365	11	-	11	1	-	17	1,000	67	4,240
	Waiawa	PAN-5	288	12	-	12	2	-	16	4,000	91	5,760
	"	WAI-1	11,650	90	2,590	2,680	16.5	92	100	1,016,000	5,722	344,880

1/ Price Base: 1973 - includes estimated construction, engineering, land rights, and project administration costs.

2/ Includes 5-7/8 percent amortization of installation cost and estimated maintenance cost.

3/ Alternative site to replace all other Waikele Watershed structures.

Both structures would be located on intermittent streams and would contain runoff water only after heavy rainstorms. The location of the HOR-1 structures is brush-covered land, while sugarcane is grown on the bottom lands of HOL-1. Only the cropland under the embankment (about 2 acres) would be lost to production.

The structures in this watershed have a high priority for installation because: (1) they would be the most efficient of all the proposed structures in terms of reducing sediment yield to Pearl Harbor, (2) a similar reduction in sediment yields by other methods cannot be achieved at a comparable cost, (3) the structures would control runoff from about 6,100 acres of land, of which 4,000 acres is likely to continue in agricultural production, and (4) the multipurpose structures would provide maximum benefits for the people in the watershed.

Waikele Watershed--The five proposed sediment basins would reduce sediment yield from this watershed by an estimated 13,400 tons/year. Sediment reduction benefits in Pearl Harbor attributable to the structures would include decreased dredging, development of the oyster resource, and recreational usage of the harbor. These benefits are estimated at $67,000 per year.

All structures would be located in brush covered lands, except for WKL-2 which is on pineapple land. Of the five structures, two have a high priority of installation since they account for 85 percent of the total sediment trapped in this watershed. These two (POL-1 and WKL-2) would control about 10,200 acres, of which nearly 5,000 acres are likely to continue in agricultural production. The other three structures (WKL-3, WKL-4, and KIP-2) would control about 1,200 acres of pineapple land currently proposed for urban development. Installation of these three structures would depend on the urban development timetable which could not be ascertained.

As an alternative to the five structures, a single structure (WKL-1) was evaluated to control most of the sediment producing areas of Waikele and Kipapa Streams. WKL-1 would reduce sediment yield to Pearl Harbor by an estimated 32,360 tons/year. Average annual sediment reduction benefits attributable to this structure are estimated at $140,400.

The structure would be located on brush covered lands. Part of the sediment would encroach on existing munition storage facilities of the U.S. Armed Forces. Costs of relocating these facilities were not included in the evaluation since a recent military announcement indicated that these facilities would be relocated.

Waiawa Watershed--There are five structures proposed for this watershed; four would be sediment basins only, while the fifth (WAI-1) would have flood protection, sediment reduction, and recreation purposes.

These structures would reduce sediment yield by an estimated 4,830 tons/year. Sediment reduction benefits in Pearl Harbor consisting of decreased dredging potential, oyster sales, and public recreational usage are estimated at $31,900 per year. The structure on Waiawa Stream (WAI-1) would also provide flood protection for about 250 acres containing crops, residences, and public property. Average annual flood damage reduction benefits are estimated at $60,500. Recreational use of the WAI-1 site would also provide an estimated $120,000 in annual benefits.

The four sediment basins would control 4,300 acres, about 2,000 acres of which is cropland currently programmed for urban development. The feasibility of installing these basins would also depend on the urban development schedule which could not be ascertained. Once the proposed developments become established, sediment yields would be substantially reduced and the large sediment basins would not be needed. During the construction period, erosion control measures are required by the City and County of Honolulu grading ordinance. For these reasons the structures in this watershed were assigned lower priorities for installation.

Table 5 summarizes the estimated sediment yields that could be achieved by installation of the various conservation practices and structural measures.

Land Use Changes

Changes in land use to reduce sediment yields would be most effective in the major agricultural areas, since sugarcane and pineapple lands are the second and third highest sediment producers in the basin. However, shifting these lands to lower sediment producing uses would result in a substantial loss of gross state output.15/ An LP model was used to estimate the losses in gross output that would result from land use changes needed to meet certain sediment levels.

The analysis centered on the Honouliuli, Waikele, and Waiawa Watersheds since they contain all of the major agricultural lands that drain into Pearl Harbor. For each watershed, the land use changes needed to achieve certain levels of sediment reduction and the effects of these changes on island output were estimated. The following assumed conditions were evaluated and compared with current production levels:

1. Existing conservation practices and urban development.

15/ Gross state output is estimated by multiplying the wholesale value of production by a total output multiplier. The multipliers are from Interindustry Study of the Hawaiian Economy, Department of Planning and Economic Development, State of Hawaii, 1972.

Table 5. Estimated Sediment Yield to Pearl Harbor for Present & Projected Conditions (Tons/Year).

Watershed	Present Yield	After Current Conservation Practices Installed	After Recommended Conservation Practices Installed	After Structural Measures Installed
Honouliuli	15,460	14,620	11,160	1,970
Waikele	55,750	49,980	42,430	29,030/10,030*
Waiawa	12,710	11,980	9,440	4,610
Waimalu	11,670	7,380	7,370	7,370
Aiea	80	80	80	80
Halawa	560	560	550	550
TOTAL	96,230	84,600	71,030	43,610/24,610

*Installation of structures POL-1, WKL-2, WKL-3, WKL-4 and KIP-2 would result in estimated sediment yield of 29,030 tons/year.

Installation of alternative WKL-1 structure would result in sediment yield of 10,030 tons/year.

2. Existing conservation practices, all developing and proposed urban developments completed.

3. Planned conservation practices installed, existing urban development.

4. Planned conservation practices installed, all developing and proposed urban developments completed.

In each case the objective was to maximize gross state output resulting from the watershed production, while meeting the state conditions. Three additional assumptions were made: (1) only those commodities grown in the watershed will be grown in the future; (2) lands currently irrigated will continue under present irrigation methods, and (3) sugarcane and pineapple production are not allowed to exceed current levels.

EVALUATION OF ALTERNATIVE PLANS

The initial Pearl Harbor analysis was based on land use change as the alternative to each of the other sediment control programs. This treatment uses gross state output (unduplicated annual production of goods and services) reductions resulting from changes in land use that would be required to meet specified harbor sediment levels as a benefit for an alternative that does not reduce production. There is no certainty that these land use changes would occur if no practical alternative existed, but they can be viewed at this point as the opportunity cost of the evaluated treatments. The conservation practices, land use changes, and structural measures incorporated in the plans allow sediment reduction without significantly disturbing agricultural activity. The physical and institutional feasibility of implementing the minor land use changes, which can reduce sedimentation without seriously disturbing the island economy, must be determined. Landownership and locational constraints may render any such land use change infeasible. Sediment levels are stated in tons per watershed and correspond to reductions of approximately 10 and 40 percent.

The result of the LP analysis of the effects of land use change are shown in Tables 6, 7, and 8, following the account displays. Three watersheds (Honouliuli, Waikele, and Waiawa) contain significant agriculture and are evaluated. The LP analysis consistently indicates that reductions in sugarcane acreages on steep lands are required to significantly reduce sedimentation. Although it is unlikely that land use changes would be used to reduce sediment, the economic effects of this alternative is important. These effects can be identified by comparing costs in Item 4 of the tables. The runs represent two sediment reduction levels of approximately 10 percent and 40 percent for each of the conditions evaluated.

It should be recognized that some of these losses would be offset by gains in construction and related activities as urban development removes land from agriculture. These aspects were not evaluated for the purpose of this study.

Three alternative plans were evaluated (Table 9). Plan A consists of conservation practices, minor land use changes, and high priority structural measures. Plan B includes all of Plan A and the lower priority structural measures. Plan C is identical to Plan B, except that the five structures located in Waikele are replaced by a single larger structure. The beneficial and adverse effects of the alternatives on national economic development (NED), environmental quality (EQ), regional development (RD), and social well-being (SWB) are displayed and provide a basis for comparing alternatives.

The environmental quality addendum and the national economic development summary of the three alternative plans are displayed in Table 10.

Table 6. Summary: LP Analysis of Land Use Change Alternatives, Honouliuli Watershed, July 1973

ITEM	UNIT	EXISTING	Condition 1 [a]		Condition 2 [b]	
			Run #1	Run #2	Run #3	Run #4
1. SEDIMENT YIELD	Tons	15,460	13,659	9,106	13,659	9,106
Reduction	%	--	10	40	10	40
2. LAND USE						
Sugarcane	Acres	3,280	3,315	2,428	3,132	2,116
Pineapple	"	530	627	461	536	509
Pasture	"	1,354	587	0	326	0
Forest	"	2,107	2,742	4,382	2,547	3,916
Urban [c] - Established	"	80	80	80	810	810
Being Developed	"	--	--	--	--	--
Proposed	"	730	--	--	--	--
Other (Gully, military, etc.)	"	386	386	386	386	386
Div. crops	"	--	--	--	--	--
3. PRODUCTION						
Sugar	Tons	170,000	170,000	131,000	155,395	115,255
Pineapple	"	9,150	9,150	9,150	9,150	9,150
4. GROSS OAHU PRODUCT	$1,000	6,598	6,602	5,292	6,107	4,770
Cost - Proposed Urban Dev.	"	--	--	--	966	966
Cost - Sediment Reduction	"	--	--	1,581	432	1,104
Effect - Land Treatment	"	--	+4	+275	+43	+243

a/ Condition 1 - Current conservation practices completed, existing urban area.
b/ Condition 2 - Current conservation practices and proposed urban developments completed.
c/ Established and being developed urban areas consist of all land zoned as Urban District under the State Land Use Law. Proposed urban areas are lands under consideration for State Land Use District boundary changes or known to be contemplating requests for such changes by the State Land Use Commission staff.

Table 7. Summary: LP Analysis of Land Use Change Alternatives, Waikele Watershed, July 1973

ITEM	UNIT	EXISTING	Condition 1 a/		Condition 2 b/	
			Run #1	Run #2	Run #3	Run #4
1. SEDIMENT YIELD	Tons	55,750	50,278	33,519	35,614	33,519
Reduction	%	--	10	40	36	40
2. LAND USE						
Sugarcane	Acres	6,242	6,117	1,734	1,773	1,773
Pineapple	"	7,529	7,429	6,950	7,613	7,613
Pasture	"	77	8	0	2,491	808
Forest	"	9,411	9,705	14,575	6,762	8,445
Urban c/ - Established	"	4,761	4,761	4,761	11,090	11,090
Being Developed	"	1,249	1,249	1,249	--	--
Proposed	"	5,080	--	--	--	--
Other (Gully, military, etc.)	"	5,146	5,146	5,146	4,686	4,686
Div. crops d/	"	385	385	385	385	385
3. PRODUCTION						
Sugar	Tons	295,000	295,000	87,297	84,279	84,279
Pineapple	"	139,000	139,000	139,000	139,000	139,000
4. GROSS OAHU PRODUCT	$1,000	24,025	24,009	17,084	16,999	16,994
Cost - Proposed Urban Dev.	"	--	--	--	5,191	5,191
Cost - Sediment Reduction	"	--	1,835	9,405	1,835	2,357
Effect - Land Treatment	"	--	+1,819	+2,464	e/	+517

a/ Condition 1 - Current conservation practices completed, existing urban areas.

b/ Condition 2 - Current conservation practices and proposed urban developments completed.

c/ Established and being developed urban areas consist of all land zoned as Urban District under the State Land Use Law. Proposed urban areas are lands under consideration for State Land Use District boundary changes or known to be contemplating requests for such changes by the State Land Use Commission staff.

d/ Diversified crop production is not included in the Gross State Product. Since the diversified crops are low sediment producers and high producers of gross state product on a per acre basis, the acreage and location of the enterprises is assumed unchanging.

e/ With full urbanization, conservation practices would have negligible effect on gross state product, but would reduce sediment yield by an additional 2,793 tons.

Table 8. Summary: LP Analysis of Land Use Change Alternatives, Waiawa Watershed, July 1973

ITEM	UNIT	EXISTING	Condition 1 a/		Condition 2 b/	
			Run #1	Run #2	Run #3	Run #4
1. SEDIMENT YIELD	Tons	12,710	11,502	7,715	2,524	(SAME AS RUN #3)
Reduction	%	--	10	40	80	
2. LAND USE						
Sugarcane	Acres	2,269	2,331	1,287	0	
Pineapple	"	539	330	325	301	
Pasture	"	--	--	--	--	
Forest	"	9,041	9,188	10,237	7,463	
Urban c/ - Established	"	1,915	1,915	1,915	6,728	
Being Developed	"	--	--	--	--	
Proposed	"	4,813	--	--	--	
Other (Gully, military, etc.)	"	1,861	1,861	1,861	1,133	
Div. crops d/	"	131	131	131	131	
3. PRODUCTION						
Sugar	Tons	123,500	120,000	70,647	0	
Pineapple	"	6,500	6,500	6,500	5,652	
4. GROSS OAHU PRODUCT	$1,000	4,776	4,646	3,014	577	
Cost - Proposed Urban Dev.	"	--	--	--	4,199	
Cost - Sediment Reduction	"	--	356	1,971	--	
Effect - Land Treatment	"	--	+226	+209	e/	

a/ Condition 1 - Current conservation practices completed, existing urban areas.

b/ Condition 2 - Current conservation practices and proposed urban developments completed.

c/ Established and being developed urban areas consist of all land zones as Urban District under the State Land Use Law. Proposed urban areas are lands under consideration for State Land Use District boundary changes or known to be contemplating requests for such changes by the State Land Use Commission staff.

d/ Diversified crop production is not included in the Gross State Product. Since the diversified crops are low sediment producers and high producers of gross state product on a per acre basis, the acreage and location of the enterprises is assumed unchanging.

e/ With full urbanization, conservation practices would have negligible effect on gross state product, but would reduce sediment yield by an additional 104 tons.

Table 9. Costs and Benefits of Alternative Plans

ITEM	COST			SEDIMENT REDUCTION BENEFITS (Tons/Year)
	Installation ($)		O&M* ($/Yr)	
	Total	Ave. Annual		
PLAN A				
1. Recommended Conservation Practices	528,500	71,380	0	13,570
2. Land Use Changes	158,700	11,375	0	960
3. Structures:				
Honouliuli (HOR-1 & HOL-1)	2,944,000	173,550	11,855	9,190
Waikele (POL-1 & WKL-2)	1,129,000	66,555	4,900	11,350
PLAN B				
1. Recommended Conservation Practices	528,500	71,380	0	13,570
2. Land Use Changes	158,700	11,375	0	960
3. Structures:				
Honouliuli (HOR-1 & HOL-1)	2,944,000	173,550	11,855	9,190
Waikele:				
(POL-1 & WKL-2)	1,129,000	66,555	4,900	11,350
(WKL-3, WKL-4 & KIP-2)	518,000	30,540	2,225	2,050
Waiawa (PAN-1, PAN-2, PAN-3, PAN-5, WAI-1)	6,432,000	379,165	10,715	4,830
PLAN C				
1. Recommended Conservation Practices	528,500	71,380	0	13,570
2. Land Use Changes	158,700	11,375	0	960
3. Structures:				
Honouliuli (HOR-1 & HOL-1)	2,944,000	173,550	11,855	9,190
Waikele (WKL-1)	2,097,000	123,620	8,465	32,360
Waiawa (PAN-1, PAN-2, PAN-3, PAN-5, WAI-1)	6,432,000	379,165	10,715	4,830

*Maintenance costs associated with conservation practices and land use changes are not shown because this maintenance would be part of normal farming operations.

Honouliuli

The current level of sediment reaching Pearl Harbor, about 15,460 tons, will be reduced to 14,620 tons by conservation practices currently being implemented. An evaluation of the material presented in Table 6 indicates that an additional reduction of about 960 tons would be possible by minor shifts in land use with no significant effect on the state economy. Below this level, reductions in net sediment will be accompanied by reductions in gross state output. A tested reduction from 13,660 to 9,106 tons resulted in gross state output declining by $1.31 million or $288/ton of sediment.

Waikele

Current sediment levels will be reduced from 55,750 to about 50,000 tons by conservation practices currently being implemented. An evaluation of Table 7 indicates that a further reduction, to 33,519 tons, would result in a gross output reduction of $6.925 million or $413/ton of sediment.

Waiawa

A reduction in sediment reaching Pearl Harbor from the current level of 12,710 to 11,980 tons per year will result from the conservation practices currently being implemented. An additional 478-ton reduction by land use changes would reduce gross state output by $130,000 or $275/ton. The LP model was also employed to test the economic impact of a sediment reduction from 11,502 to 7,715 tons (Table 8). The cost in terms of reduced gross state output for this change was $1.632 million or $430/ton. Full development of proposed urban areas would reduce sediment to about 2,524 tons.

System of Accounts

In Honouliuli it is assumed that the conservation practices currently being implemented and the additional 960 tons/year of sediment reduction available through land use change are completed. This means an initial net sediment level from Honouliuli of 13,660 tons/year. In the case of Waikele the initial sediment level is 49,980 tons/year, and for Waiawa 11,980 tons/year. Additional reductions would involve reductions in gross state output of from $275 to $690/ton/year of sediment.

Plan A

The 35,070 tons of sediment controlled by the plan includes: 960 tons from land use change in Honouliuli, 13,570 tons from additional conservation practices, and 20,540 tons from structures. Plan A, as an alternative to land use change, avoids loss of agricultural income representing $72.91/ton of sediment, net of cash operating costs plus interest on operating capital, for the first 25,577 tons. An additional 8,533 tons of controlled sediment has an associated, estimated, net income of $131.42/ton of sediment. The 960 tons

controlled by minor shifts in land use at Honouliuli is available with no reduction in sugar production. The total net income protected by the plan equals $2.986 million. Gross factor payments[16/] accruing to the region and associated with this production are $7.244 million. Honouliuli land use change would require the establishment of forest on 635 acres of land at a cost of $250/acre. This outlay of $158,700 ($9,355 annually) is included as a construction cost.

Plan B

The 41,950 tons of sediment controlled includes: 960 tons from Honouliuli land use shift, 13,570 from additional conservation practices, and 27,420 tons from structures. Plan B, as an alternative to land use change, avoids the loss of agriculture production representing $72.91 income, net of cash operating costs plus interest on operating capital, per ton of sediment to a limit of 25,577 tons. An additional 15,413 tons of controlled sediment represents a protected net of $131.42 per ton. The final 960 tons can be controlled with no reduction in sugar production. The total net income protected by the plan equals $3.890 million. Gross factor payments accruing to the region and associated with this production are $9.440 million. The suggested land use change in Honouliuli requires the establishment of forest on 635 acres of land at a cost of $250 per acre. This outlay of $158,700 ($9,355 annually) is included as a construction cost.

Plan C

The 60,910 tons of sediment controlled includes: 960 tons from the Honouliuli land use change, the 13,570 from additional conservation practices, and 46,380 tons from structures. Plan C avoids the loss of agricultural production representing $72.91 income, net of cash operating costs plus interest on operating capital, per ton of sediment to a limit of 25,577 tons. An additional 34,373 tons of controlled sediment represents a protected net of $131.42 per ton. The final 960 tons can be controlled with no reduction in sugar production. The total net income protected by the plan equals $6.382 million. Gross factor payments accruing to the region and associated with this production are $15.496 million. The suggested land use change in Honouliuli requires the establishment of forest on 635 acres of land at a cost of $250 per acre. This outlay of $158,700 ($9,355 annually) is included as a construction cost.

16/ Gross factor payments are payments to land, labor capital, and management.

National Economic Development - Plan A

Component		Annual Amount
NED Benefits		
a. Value of goods and services:		
Protected production [1/]		--
Recreation [2/]	$	39,400
Reduced dredging		30,400
b. Flood benefits		61,200
c. External economies [3/]		--
d. Oyster fishery		35,600
e. Underemployed resources [4/]		218,000
TOTAL	$	384,600
NED Costs		
Project Installation ($4,760,200 @ 5-7/8%) [5/]	$	280,614
O & M		16,755
TOTAL	$	297,369

NOTE: See page 55 for footnotes.

Environmental Quality - Plan A

Measures of Effects

1. Periodically inundate 50 acres of sugarcane land and 40 acres of brush covered land in gulches above the dams.

2. Control erosion by provision of 100 miles of diversions in agricultural lands, implementation of critical area planting on 1,600 acres of land, and implementation of pasture management practices on 1,500 acres.

3. Reduce sedimentation in Pearl Harbor by an estimated 35,070 tons per year.

4. Turbid conditions in Pearl Harbor during heavy rainstorms would remain since the sediment basins would not remove the very fine particles.

Components	Measures of Effects	
	State of Hawaii	Rest of Nation
	- - - Dollars - - -	
Income:		
Beneficial effects:		
A. The value of increased output of goods and services to users residing in the region.		
1. Protected Production[1/]	--	--
2. Recreation[2/]	39,400	--
3. Reduced Dredging	--	30,400
4. Flood Benefits	61,200	--
5. Oyster Fishery	35,600	--
6. Additional Income to Region[4/]	218,000	--
Total beneficial effects	354,200	30,400

Components	Measures of Effects	
	State of Hawaii	Rest of Nation
	- - - Dollars - - -	
Income:		
Adverse effects:		
A. The value of resources contributed from within the region to achieve the outputs.		
1. Project installation	4,567	275,957
2. O&M	16,755	--
Total adverse effects	21,412	275,957
Net beneficial effects	332,788	-245,557

Note: See page 55 for footnotes.

Net Income Generated in Region During Construction - Plan A

Item	Total	Purchases in Region	Net Income to Region: Labor	Other	Total
		(Million Dollars)			
Construction cost 6/	4.038	2.948	2.261	0.929	3.190
Engineering	.350	.350	--	.350	.350
Project administration	.293	.293	--	.293	.293
Land acquisition	.079	.079	--	--	--

Employment - Plan A

Item	Employment per Million Dollar Sales	Total Employment 7/
Installation Cost Excluding Land Acquisition	73.0219	342

NOTE: See page 55 for footnotes.

Social Well-Being Accounts - Plan A

POPULATION DISTRIBUTION BY INCOME CLASS

Category of Beneficiary	Distribution by Household Income Class 1	2	3	4
	(Percent)			
Fishing (Oysters)[8/]	28.6	36.6	21.9	12.9
Recreation[9/]	12.7	11.6	30.1	45.6
Flood control[9/]	13.0	21.0	47.0	19.0

BENEFIT DISTRIBUTION BY INCOME CLASS

Category of Beneficiary	Benefit by Income Class[8/] 1	2	3	4
	(Dollars/year)			
Fishing (Oysters)	10,182	13,030	7,796	4,592
Recreation	5,004	4,570	11,859	17,966
Flood Control	7,956	12,852	28,764	11,628

NOTE: See page 55 for footnotes.

National Economic Development - Plan B

Component		Annual Amount
NED Benefits		
a. Value of goods and services:		
Protected production [1/]		--
Recreation [2/]	$	188,700
Reduced dredging		39,600
b. Flood benefits		121,700
c. External economies [3/]		--
d. Oyster fishery		39,000
e. Underemployed resources [4/]		365,400
	TOTAL $	754,400
NED Costs		
Project Installation ($11,710,200 @ 5-7/8%) [5/]	$	690,316
O & M		29,695
	TOTAL $	720,011

NOTE: See page 55 for footnotes.

Environmental Quality - Plan B

Measures of Effects
1. Periodically inundate 50 acres of sugarcane land and 130 acres of brush covered land in gulches above the dams.
2. Control erosion by provision of 100 miles of diversions in agricultural lands, implementation of critical area planting on 1,600 acres of land, and implementation of pasture management practices on 1,500 acres.
3. Reduce sedimentation in Pearl Harbor by an estimated 41,950 tons per year.
4. Turbid conditions in Pearl Harbor during heavy rainstorms would remain since sediment basins would not remove the very fine particles.

REGIONAL DEVELOPMENT - PLAN B

Components	Measures of Effects: State of Hawaii	Measures of Effects: Rest of Nation
	- - - Dollars - - -	
Income:		
Beneficial effects:		
A. The value of increased output of goods and services to users residing in the region.		
1. Protected Production[1/]	--	--
2. Recreation[2/]	188,700	--
3. Reduced Dredging	--	39,600
4. Flood Benefits	121,700	--
5. Oyster Fisheries	39,000	--
6. Additional Income to Region[4/]	365,400	--
Total beneficial effects	714,800	39,600

Components	Measures of Effects: State of Hawaii	Measures of Effects: Rest of Nation
	- - - Dollars - - -	
Income:		
Adverse effects:		
A. The value of resources contributed from within the region to achieve the outputs.		
1. Project installation	235,152	455,164
2. O&M	29,695	
Total adverse effects	264,847	455,164
Net beneficial effects	449,953	-415,564

Note: See page 55 for footnotes.

June 1975

Net Income Generated in Region During Construction - Plan B

Item	Total	Purchases in Region	Net Income to Region		
			Labor	Other	Total
	----------Million Dollars----------				
Construction cost 6/	6.626	4.837	3.711	1.524	5.235
Engineering	.596	.596	--	.596	.596
Project Administration	.498	.498	--	.498	.498
Land Acquisition	3.989	3.989	--	--	--

Employment - Plan B

Item	Employment Per Million-Dollar Sales	Total Employment 7/
Installation Cost Excluding Land Acquisition	73.0219	564

NOTE: See page 55 for footnotes.

Social Well-Being Accounts - Plan B

Category of Beneficiary	Distribution by Household Income Class 1	2	3	4
	----------Percent----------			
Fishing (Oysters)[7/]	28.6	36.6	21.9	12.9
Recreation[8/]	12.7	11.6	30.1	45.6
Flood control[8/]	13.0	21.0	47.0	19.0

Category of Beneficiary	Benefit by Income Class[8/] 1	2	3	4
	----------Dollars/year----------			
Fishing (Oysters)	11,154	14,274	8,541	5,031
Recreation	23,965	21,889	56,799	86,047
Flood control	15,821	25,557	57,199	23,123

NOTE: See page 55 for footnotes.

National Economic Development - Plan C

Component		Annual Amount
NED Benefits		
a. Value of goods and services:		
Protected production [1/]		--
Recreation [2/]	$	225,900
Reduced dredging		56,200
b. Flood benefits		121,700
c. External economies [3/]		--
d. Oyster fishery		58,600
e. Underemployed resources [4/]		389,700
TOTAL	$	852,100
NED Costs		
Project Installation ($12,160,200 @ 5-7/8%) [5/]	$	716,844
O & M		31,035
TOTAL	$	747,879

NOTE: See page 55 for footnotes.

Environmental Quality - Plan C

Measures of Effects
1. Periodically inundate 50 acres of sugarcane land and 230 acres of brush covered land in gulches above the dams.
2. Control erosion by provision of 100 miles of diversions in agricultural lands, implementation of critical area planting on 1,600 acres of land, and implementation of pasture management practices on 1,500 acres.
3. Reduce sedimentation in Pearl Harbor by an estimated 60,910 tons per year.
4. Turbid conditions in Pearl Harbor during heavy rainstorms would remain since sediment basins would not remove the very fine particles.

REGIONAL DEVELOPMENT - PLAN C

Components	Measures of Effects	
	State of Hawaii	Rest of Nation
	- - - Dollars - - -	
Income:		
Beneficial effects:		
A. The value of increased output of goods and services to users residing in the region.		
1. Protected Production[1/]	--	--
2. Recreation[2/]	225,900	--
3. Reduced Dredging	--	56,200
4. Flood Benefits	121,700	--
5. Oyster Fisheries	58,600	--
6. Additional Income to Region[4/]	389,700	--
Total beneficial effects	795,900	56,200

Components	Measures of Effects	
	State of Hawaii	Rest of Nation
	- - - Dollars - - -	
Income:		
Adverse effects:		
A. The value of resources contributed from within the region to achieve the outputs.		
1. Project installation	234,032	482,812
2. O&M	31,035	--
Total adverse effects	265,067	482,812
Net beneficial effects	530,833	-426,612

Note: See page 55 for footnotes.

Net Income Generated in Region During Construction - Plan C

Item	Total	Purchases in Region	Income to Region		
			Labor	Other	Total
	----------Million dollars----------				
Construction cost 6/	6.894	5.033	3.861	1.586	5.447
Engineering	.707	.707	--	.707	.707
Project administration	.589	.589	--	.589	.589
Land acquisition	3.970	3.970	--	--	--

Employment - Plan C

Item	Employment Per Million-Dollar Sales	Total Employment 7/
Project Installation Excluding Land Acquisition	73.0219	598

NOTE: See page 55 for footnotes.

Social Well-Being Account - Plan C

Category of Beneficiary	Distribution by Household Income Class			
	1	2	3	4
	----------Percent----------			
Fishing (Oysters)[8/]	28.6	36.6	21.9	12.9
Recreation[9/]	12.7	11.6	30.1	45.6
Flood control[9/]	13.0	21.0	47.0	19.0

Category of Beneficiary	Benefit by Income Class[8/]			
	1	2	3	4
	----------Dollars/year----------			
Fishing (Oysters)	16,760	21,448	12,833	7,559
Recreation	28,689	26,204	67,996	103,010
Flood control	15,821	25,557	57,199	23,123

NOTE: See page 55 for footnotes.

Table 10. Pearl Harbor River Basin Type IV Report

Appraisal of Alternative Means to Alleviate Erosion and Sedimentation Damages in the Pearl Harbor Basin, Island of Oahu, Hawaii

Environmental Quality Addendum and National Economic Development Summary
(Comparison between the Maximum Benefit Plan and Other Alternative Plans)

ENVIRONMENTAL QUALITY	MAXIMUM BENEFIT PLAN C	PLAN A	PLAN B	COMPARE (PLAN C - PLAN A)	COMPARE (PLAN C - PLAN B)
Control Erosion on:					
Critical Eroding Area	1,600 acres	1,600 acres	1,600 acres	0	0
Pasture	1,500 acres	1,500 acres	1,500 acres	0	0
Reduce Sedimentation in Pearl Harbor	60,910 tons/yr.	35,070 tons/yr.	41,950 tons/yr.	+25,840 tons/yr.	+18,960 tons/yr.
Periodically Inundates:					
Sugarcane Land	50 acres	50 acres	50 acres	0	0
Non-Commercial Forest	230 acres	40 acres	130 acres	+190 acres	+100 acres
Reduction in Flood Damages	500 acres	250 acres	500 acres	+250 acres	0
Create a Lake for Beauty and Human Enjoyment	60 acres	0	60 acres	+60 acres	0
Beneficial Effects	$852,100	$384,600	$754,400	+$467,500	+$97,700
Adverse Effects	$725,309	$297,369	$720,011	+$427,940	+$ 5,298
Net Beneficial Effects	$126,791	$ 87,231	$ 34,389	+$ 39,560	+$92,402

1/ Because it is unlikely that a land use change would be required in the absence of an engineering solution to the sediment problem, the benefits associated with protecting existing production are not included.

2/ This treatment of recreation assumes 100 percent of the users are local residents. For Plans B and C, annual benefits include $120,000 from recreational use of WAI-1 reservoir.

3/ External economies are not included because the mill serving the study area is believed to be vulnerable to shifts in a number of variables. A significant reduction in production, for example, would likely stop mill operations.

4/ Includes underemployed construction labor and value added during construction period (stated as average annual benefit - 5-7/8 percent). Based on coefficients from "Interindustry Study of the Hawaiian Economy," published by the Department of Planning and Economic Development, State of Hawaii.

5/ Estimated purchase prices of these lands are $500/acre for gully lands, up to $5,250/acre for agricultural land, and $25,500/acre for urban-zoned land. Net income displaced by loss of producing acreage would be about $3,285/year for Plan A.

6/ Based on percentages from "Interindustry Study of the Hawaiian Economy," published by the Department of Planning and Economic Development, State of Hawaii. (Imports: 4 percent; labor: 56 percent; regional purchases: 17 percent; and value added: 23 percent.)

7/ Includes direct, indirect, and induced employment.

8/ Income classes are: Under 3,999; 4,000-7,999; 8,000-11,999; and over 12,000. Based on "Recreational Fishing," Department Paper No. 3, Hawaii Agricultural Experiment Station, August 1972.

9/ Income classes are: Under 7,000; 7,000-9,999; 10,000-15,000; and over 15,000. Distribution based on 1970 Census of Population for recreation benefits with flood control benefits based on the income distribution of households in zip code area 96706 (the area subject to flooding).

THE EFFECT OF URBANIZATION ON PLANS A, B, AND C

No target level of sedimentation has been established for Pearl Harbor; consequently, it is difficult to fully assess the impact of urbanization. In Honouliuli, assuming full development of proposed urban lands, a sediment level of 13,660 tons would reduce annual gross state output by $495,000 due to the urbanization of agricultural land.[17/] In Waikele, full development of the proposed urban areas would result in a sediment reduction of 14,366 tons from the initial level of about 49,980 tons. The annual loss of gross state output resulting from the change would be $7.01 million. Urbanization planned in Waiawa would reduce the initial 11,980-ton level to 2,524 tons with a corresponding loss in output of $4.20 million annually. After urbanization, minor land use changes in Waikele could reduce sediment an additional 2,095 tons with a $5,000 per year reduction in gross output. In total, 25,940 tons per year could be controlled with full development of all proposed urban areas with an $11.71 million annual loss of gross state output ($451/ton). This compares to a Plan A total of 35,070 tons, a Plan B total of 41,950 tons, and a Plan C total of 60,190 tons.

17/ This figure is derived from Table 6, runs 5 and 7, where the only factor that changes is degree of urbanization.

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Federal Agencies

Dept. of the Interior -
Geological Survey

Dept. of the Army -
Corps of Engineers

Dept. of the Navy
Dept. of the Air Force
Environmental Protection Agency

State Agencies

Dept. of Land & Natural Resources -
Division of Water and Land Development
Division of Forestry

Dept. of Planning & Economic Development -
Land Use Commission

County Agencies

Board of Water Supply, City & County of Honolulu
Dept. of Parks and Recreation
Planning Department

Others

University of Hawaii -
Land Study Bureau (defunct)
Hawaii Environmental Simulation Laboratory

South Oahu Soil and Water Conservation District
West Oahu Soil and Water Conservation District
Oahu Sugar Company
Dole Company
Del Monte Corporation

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FIGURE 1

LOCATION MAP

PEARL HARBOR BASIN

ISLAND OF OAHU, HAWAII

JULY 1973

SCALE 1:510,000

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

M7-0-22970-L

GENERAL LAND USE

- Forest
- Sugar Cane
- Pineapple
- Urban District
- Diversified Agriculture
- Grazing
- Other

Source: Urban District – Land Use Commission, State of Hawaii, Dept. of Planning & Economic Development, August 1969

LOCATION MAP

KAUAI
NIIHAU
OAHU
Pearl Harbor Basin
MOLOKAI
LANAI
MAUI
KAHOOLAWE
HAWAII
HAWAIIAN ISLANDS

FIGURE 2

GENERAL LAND USE

PEARL HARBOR BASIN

CITY AND COUNTY OF HONOLULU
ISLAND OF OAHU, HAWAII

NOVEMBER 1974

SCALE 1:96,000

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND, OREG. 974

M7-EN-22943-1

SOIL ASSOCIATIONS

LUALUALEI-FILL LAND-EWA ASSOCIATION
Nearly level and gently sloping soils on coastal plains; deep soils; shallow soils over coral, fill land and coral outcrop.

HELEMANO-WAHIAWA ASSOCIATION
Nearly level to moderately sloping soils on uplands, broken by deep gulches; deep, well-drained soils.

TROPOHUMULTS-DYSTRANDEPTS ASSOCIATION
Very steep mountain ridges and gently sloping to steep soils on side slopes; well-drained soils underlain by weathered rock, volcanic ash and colluvium.

ROUGH MOUNTAINOUS LAND-KAPAA ASSOCIATION
Very steep mountainous land broken by numerous drainageways; consists of deep gulches and narrow ridges.

LOCATION MAP

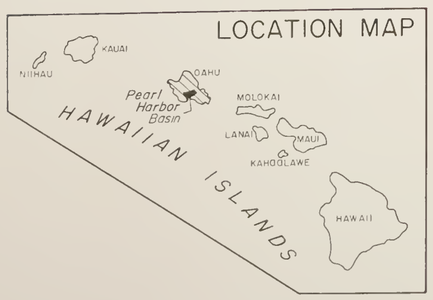


FIGURE 3
GENERAL SOIL MAP
PEARL HARBOR BASIN
CITY AND COUNTY OF HONOLULU
ISLAND OF OAHU, HAWAII

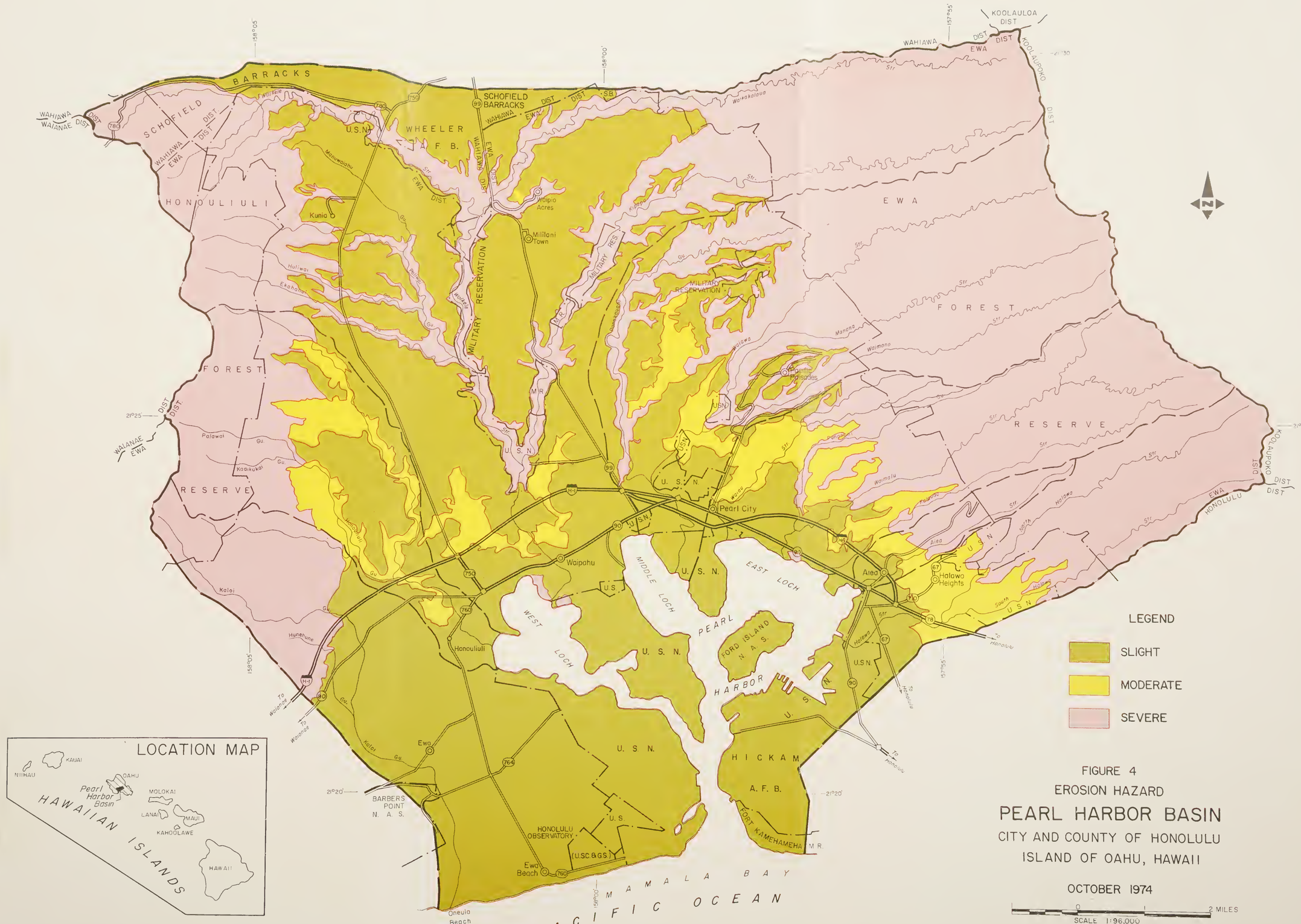
OCTOBER 1974

SCALE 1 96,000 — 0 — 2 MILES

Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.

M7-EN-22943-2

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE



LEGEND

- SLIGHT
- MODERATE
- SEVERE

FIGURE 4

EROSION HAZARD

PEARL HARBOR BASIN

CITY AND COUNTY OF HONOLULU

ISLAND OF OAHU, HAWAII

OCTOBER 1974

SCALE 1:96,000 — 0 — 2 MILES

LOCATION MAP

NOTE : THIS MAP IS INTENDED FOR GENERAL PLANNING. EACH DELINEATION MAY CONTAIN SOILS HAVING RATINGS DIFFERENT FROM THOSE SHOWN ON THE MAP. USE DETAILED SOILS MAP FOR OPERATIONAL PLANNING AND ON-SITE INSPECTION FOR MORE DETAILED DECISIONS.

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

M7-EN-22943-3

GENERAL GEOLOGY

Sedimentary Rocks

Recent

Beach & Dune Sand

Alluvium

Pleistocene

Limestone (Reefs & Dunes)

Volcanic Rocks
Quaternary

Honolulu Volcanics
Tertiary

Koolau Volcanic Series

Waianae Volcanic Series
(Upper & Lower Members)

← Cone

Geology by H. T. Stearns, 1930-1932

LOCATION MAP

KAUAI
NIIHAU
OAHU
Pearl Harbor Basin
MOLOKAI
LANAI
MAUI
KAHOOLAWE
HAWAII
HAWAIIAN ISLANDS

FIGURE 5

GENERAL GEOLOGY

PEARL HARBOR BASIN

CITY AND COUNTY OF HONOLULU
ISLAND OF OAHU, HAWAII

OCTOBER 1974

SCALE 1:96,000 — 0 — 2 MILES

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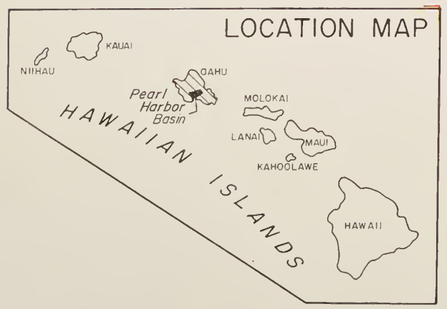
LEGEND

- FOREST
- GRASSLAND AND HERBACEOUS TYPE
- SUGAR CANE
- PINEAPPLE
- DIVERSIFIED AGRICULTURE
- PASTURE
- URBAN AND URBANIZING AREAS
- OTHER

LOCATION MAP



SOURCE : HAWAII FOREST TYPE MAPS
HAWAII DEPARTMENT OF LAND & NATURAL RESOURSES, DIVISION OF FORESTRY IN COOPERATION WITH U.S.D.A. FOREST SERVICE PACIFIC SOUTHWEST FOREST & RANGE EXPERIMENT STATION.
(HONOLULU, HAWAII, 1964)

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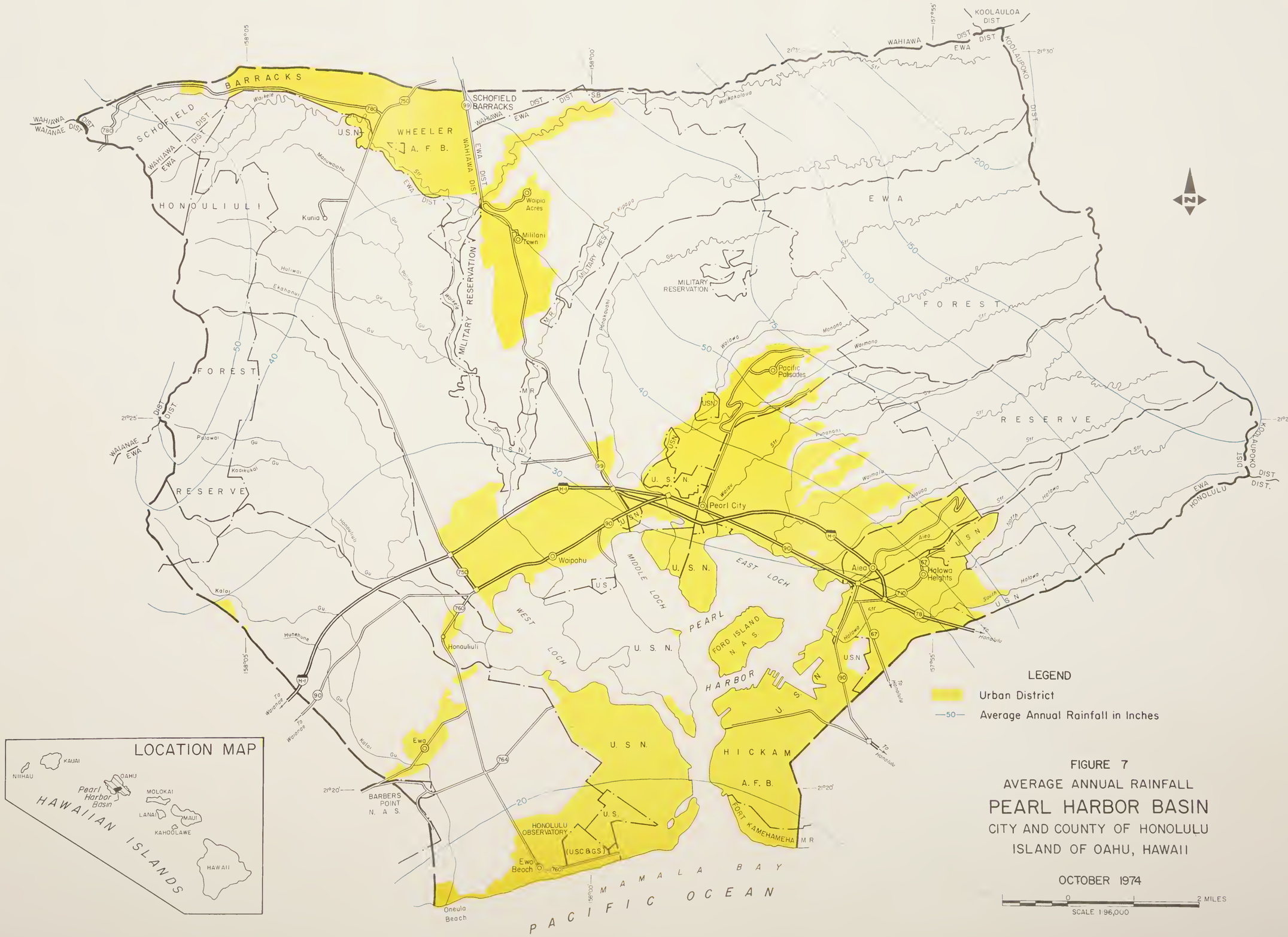
FIGURE 6
VEGETATIVE TYPES
PEARL HARBOR BASIN
CITY AND COUNTY OF HONOLULU
ISLAND OF OAHU, HAWAII

OCTOBER 1974

0 2 MILES
SCALE 1:96,000

M7-EN-22934-5



LOCATION MAP

LEGEND

Urban District

—50— Average Annual Rainfall in Inches

FIGURE 7

AVERAGE ANNUAL RAINFALL

PEARL HARBOR BASIN

CITY AND COUNTY OF HONOLULU

ISLAND OF OAHU, HAWAII

OCTOBER 1974

0 2 MILES

SCALE 1:96,000

SOURCE: ISOHYETS FROM BOARD OF WATER SUPPLY CITY & COUNTY OF HONOLULU, 1974

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M7-EN-22943-6

LAND OWNERSHIP

- Federal
- State and City & County of Honolulu
- Private
- Large Parcel Major Owners
- Small Parcel Individual Owners

LOCATION MAP

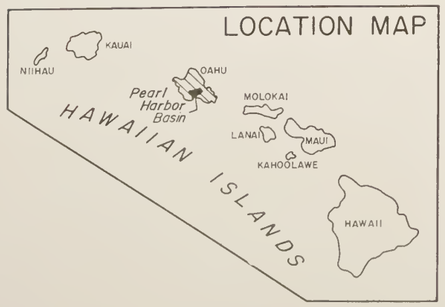

FIGURE 8

LAND OWNERSHIP MAP

PEARL HARBOR BASIN

CITY AND COUNTY OF HONOLULU

ISLAND OF OAHU, HAWAII

OCTOBER 1974

SCALE 1:96,000

Source: Land Study Bureau, University of Hawaii, Jan. 1964.

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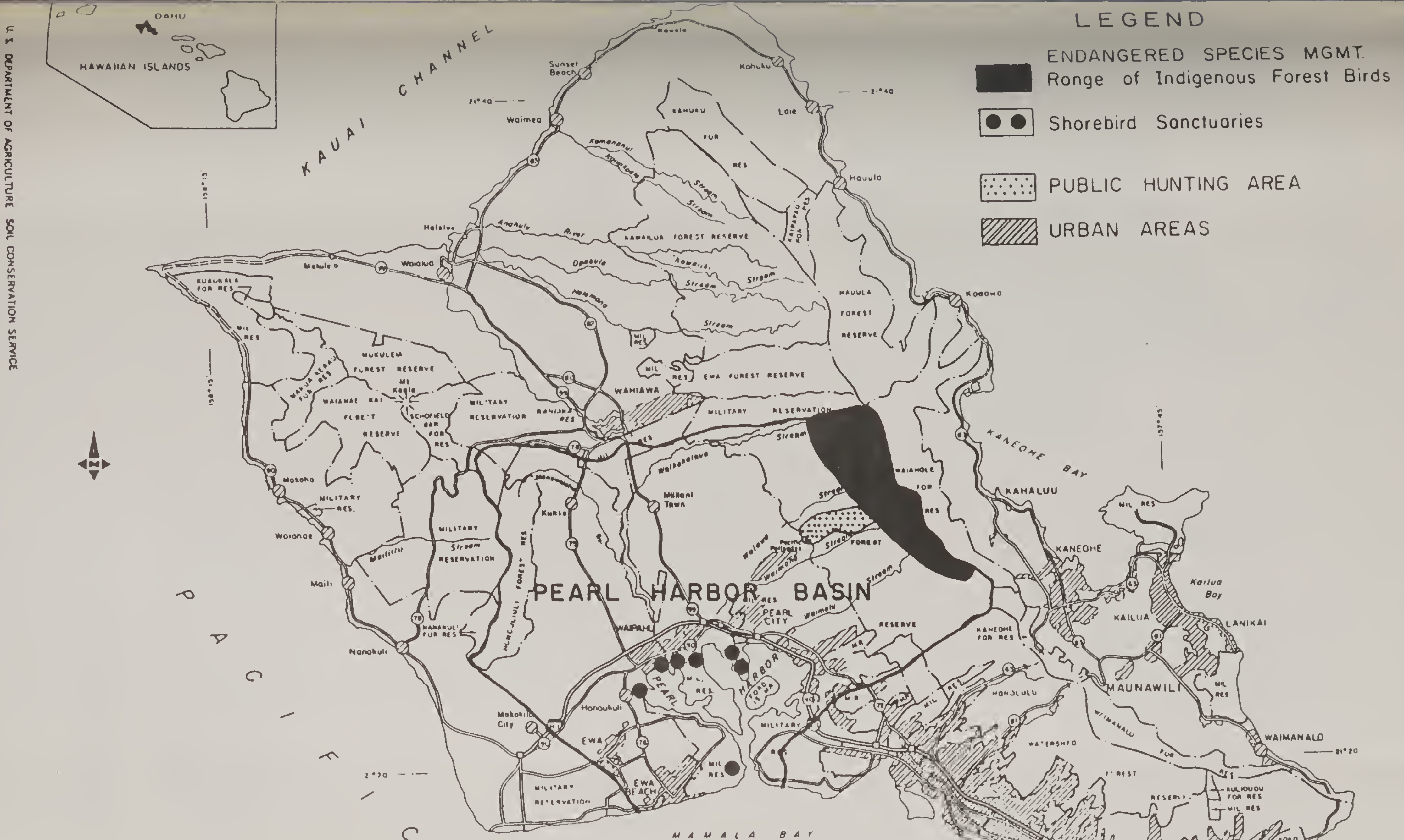

FIGURE 9
WILDLIFE IMPACT AREA
PEARL HARBOR BASIN
ISLAND OF OAHU, HAWAII

JULY 1973

0 1 2 3 4 5 6 7 8 MILES
SCALE 1:316,800

PROJECT LOCATION

Study Area Boundary

Watershed Boundary

Drainage Area Controlled by Structure

Multi-Purpose Structure

Sediment Detention Structure

POL-1 Structure Designation

D.A. 1895 ac. Drainage Area Acreage

LOCATION MAP

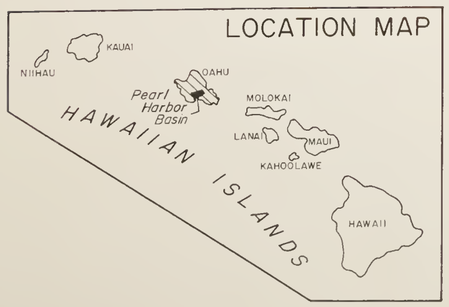

FIGURE 10

PROJECT LOCATION MAP

PEARL HARBOR BASIN

CITY AND COUNTY OF HONOLULU

ISLAND OF OAHU, HAWAII

OCTOBER 1974

SCALE 1:96,000

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FIGURE IIA

FLOOD PRONE AREA MAP

PEARL HARBOR BASIN

CITY AND COUNTY OF HONOLULU

ISLAND OF OAHU

JULY 1973

1/4 0 1/4 1/2 3/4 1 MILE

SCALE 1:24,000

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND, OR 1976

M7-L-23016A

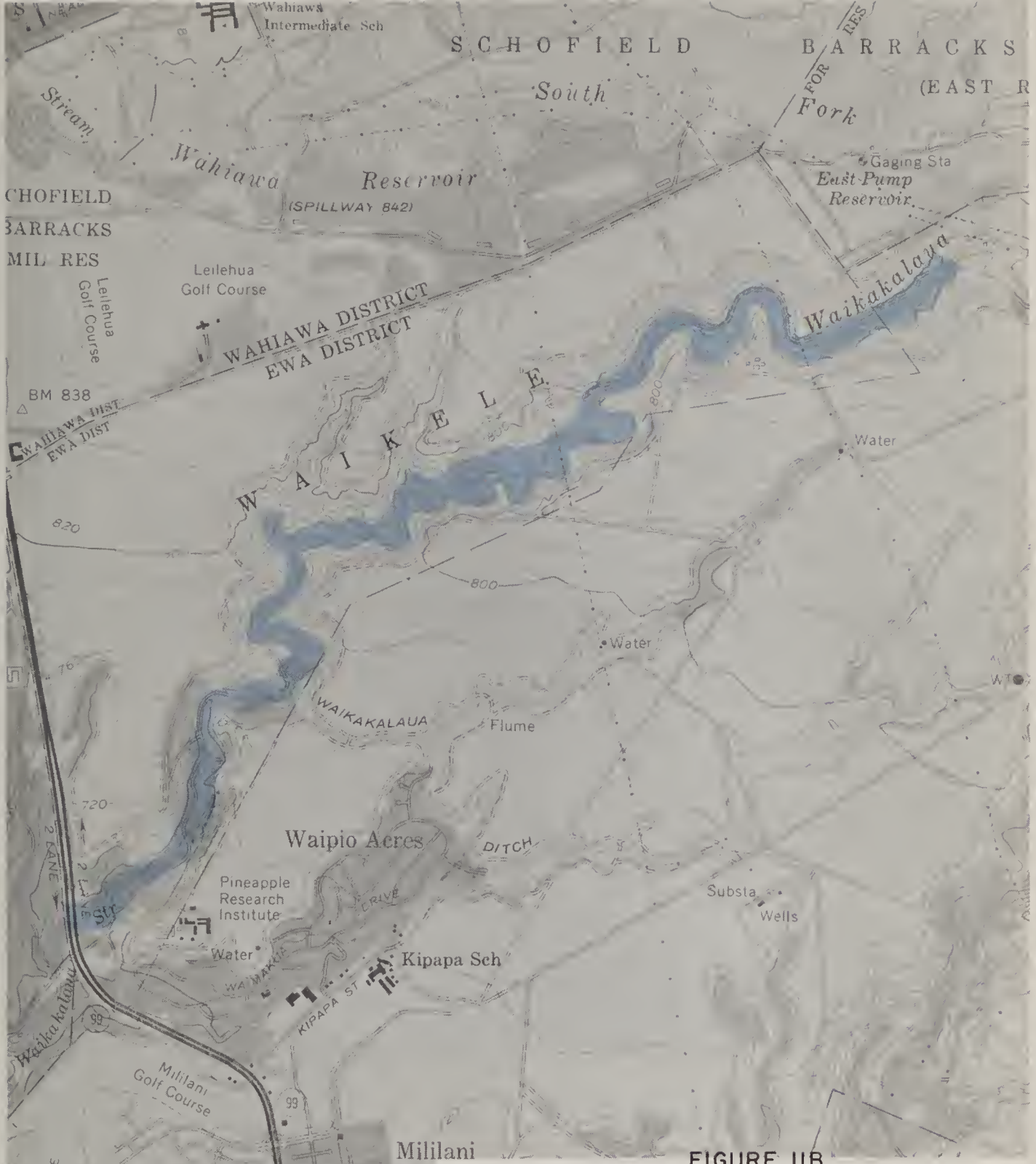


FIGURE IIB

FLOOD PRONE AREA MAP

PEARL HARBOR BASIN

CITY AND COUNTY OF HONOLULU

ISLAND OF OAHU

JULY 1973

1/4 0 1/4 1/2 3/4 1 MILE

SCALE 1:24,000

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND, OR 1976

M7-L-23016B

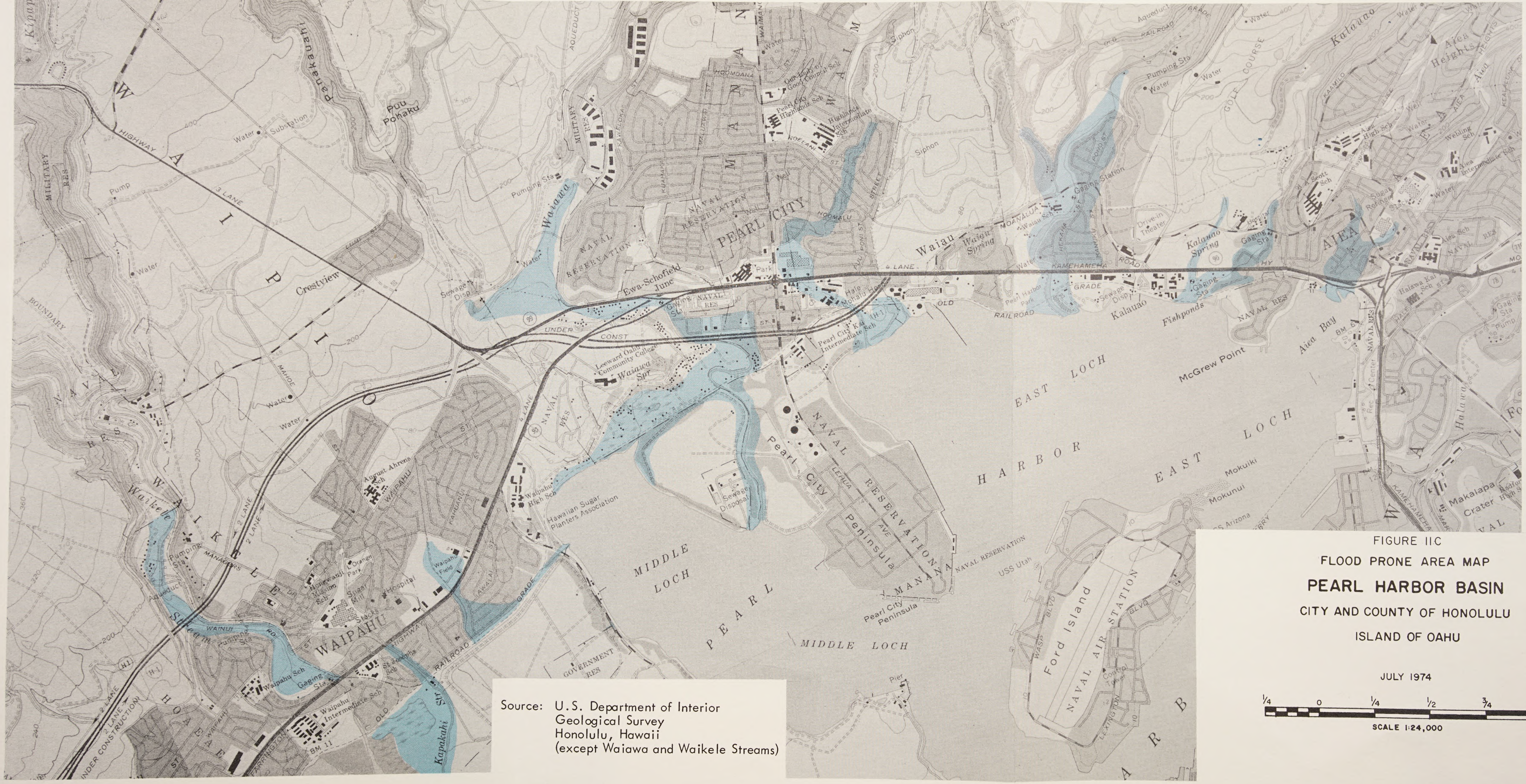


FIGURE IIC

FLOOD PRONE AREA MAP

PEARL HARBOR BASIN

CITY AND COUNTY OF HONOLULU

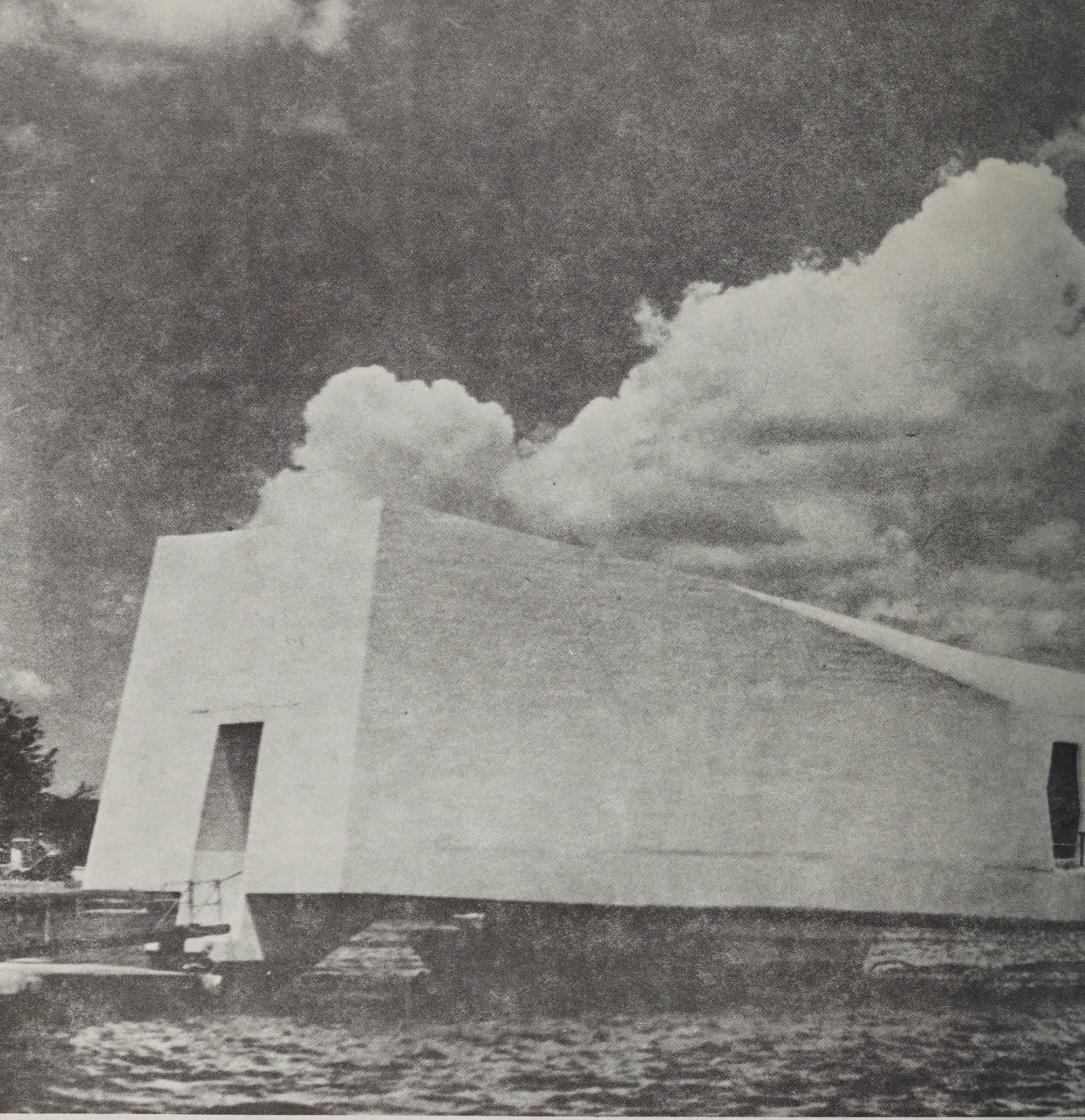
ISLAND OF OAHU

JULY 1974

1/4 0 1/4 1/2 3/4 1 MILE

SCALE 1:24,000

Source: U.S. Department of Interior
Geological Survey
Honolulu, Hawaii
(except Waiawa and Waikele Streams)



Arizona Memorial, Pearl Harbor *(Hawaii Visitors Bureau Photo)*